Alberta Hail Project
Field Program 1984

Atmospheric Sciences

ALBERTA
RESEARCH
COUNCIL

Natural Resources Division
Atmospheric Sciences Department

Alberta Hail Project
Field Program 1984

Atmospheric Sciences

ALBERTA
RESEARCH
COUNCIL

Natural Resources Division
Atmospheric Sciences Department

Copies of this report are available from:
Atmospheric Sciences Department
Alberta Research Council
Provincial Building
4920 - 51 Street
Red Deer, Alberta
T4N 6K8
or:
Editing and Publications Sales Department
Alberta Research Council
5th Floor, Terrace Plaza
4445 Calgary Trail South
Edmonton, Alberta, Canada
T6H 5R7

Preface

This report continues the series of annual field program reports and covers the 1984 field research activities of the Alberta Research Council's Atmospheric Sciences Research Program.

Storm activity was down somewhat from previous years, with a third of the days during the season having no significant convection. As a result, compared to last year, this field season was not as productive in terms of the amount of data gathered but was certainly successful from the standpoint of quality of data collected. Many research aircraft flights were terminated, lacking suitable clouds for experiments. Hail activity was down from previous years with hail reports for the year at 11 percent below average.

Of considerable note this year, was the 11th annual North American Interstate Weather Modification Council Meeting, 14-16 August in Red Deer. The meeting was hosted by Alberta Agriculture's Advisory Committee on Weather Modification with assistance from the Alberta Research Council. Numerous seminars were given by Atmospheric Sciences Department personnel in a day long session that also included a tour of the project facilities for the conference participants.

This report summarizes the various activities, experiments and data collected during the 1984 summer field season. The report material has been contributed by personnel of the Alberta Research Council, INTERA Technologies Ltd. and Montana State University. Assimilation and editing of this report was provided by R. Deibert with assistance by Ms. L. Shannon. These many contributions are gratefully acknowledged. A special acknowledgement and appreciation is made to all the area farmers who maintained precipitation measuring and sampling stations and to those throughout the province who supplied storm information data. The continued interest and support of Alberta Agriculture and its Advisory Committee on Weather Modification is also most appreciated.

J.H. Renick, Manager
Weather Modification Projects
Atmospheric Sciences Department

Summary 1984

Hail experiment
There were 18 flights for hail experiments and general thunderstorm studies, accounting for 49 hours of flight time. This time was divided between controlled seeding experiments and studies of natural or operationally seeded storms. A total of 231 cloud water rime samples was collected using the DRI and ARC rime rods.

Rain experiment
There were 76 clouds investigated for potential rain experiments on 19 days. Thirty-four of these clouds were randomly treated using the standard cloud top seeding method, dry ice or placebo.

Plume tracing
A plume tracing study was conducted from 10-31 July in the I.P. Krick ground-based generator cloud seeding area south of Calgary. Thirteen flights measuring ice nuclei were made totalling 36.9 hours; 122 plumes were encountered.

Lightning
Research on forecasting of damaging lightning flashes from radar observations was conducted in late August. Data were successfully gathered on 17 August for approximately 1 hour.

Cloud seeding
During the operational period from 20 June to 31 August, 30 days required cloud seeding missions. Operational seeding was again carried out only in the south area (Twps. 26-36). This year 6568 pencil flares and 351 base flares were used. Acetone solution usage was 83 imperial gallons.

Radars
The S-band radar operated for 490 hours between 1 May and 1 September. Four-channel S-band data were recorded on 366 tapes representing 377 hours on 56 days. The C-band system provided 1065 hours of surveillance. One-channel C-band data were recorded on 244 tapes representing 777 hours on 54 days.

Hailstone network
A network of 653 volunteer stations was established within a 13,400 km² area around Red Deer from 20 June to 15 August to collect time-integrated hailstone samples from the ground. A total of 157 hail samples (from 25 hail days) was obtained.

Precipitation measurement network
A volunteer operated precipitation measuring network of 635 stations was established within the project area from 1 June to 1 September. Over 80 percent of the operators returned completed rainfall records for the three months.

Storm forecasting
A new ASc4 "advection forecast" model was developed and tested during the summer. The weather office was operational from 13 June to 31 August. The Meteorological Data Facility became operational in July. Forecasts made between 20 June and 31 August (cloud seeding operational period) were 75 percent correct to within one CDC and 85 percent correct in forecasting hail/no hail. Special research aircraft flights on 19 July and 6 August mapped the formation and breakdown of the capping inversion.

Hailfall activity
During the operational cloud seeding period, hail was reported in the project area on 34 days, 2180 hail reports were received. During the hail season (1 June - 30 September), there were 45 hail days in the project area (4 percent below the 1957 to 1984 average). The 2342 hail reports during the period were 11 percent below average. Major hailstorms occurred on 6, 21, 28 July and 6, 18, 19 August.

Table of Contents

Section	Author	Page
Preface	J. Renick	iii
Summary	R. Deibert	iv
Introduction	R. Deibert	1
Field experiments		1
Hail	D. Rogers	1
Rain	B. Kochtubajda	5
Plume tracing	J. Heimbach (Montana State)	7
Lightning	G. Goyer	7
Field operations		8
Cloud seeding	R. Rudolph (INTERA)	8
Radars/computers	M. Stanley-Jones/R. Drobig	11
Hailstone network	L. Wojtiw/A. Davis	13
Precipitation measurement network	L. Wojtiw/C. Ewing	15
Storm forecasting	G. Strong/W. Wilson/G. Lamb	15
Hailfall activity	L. Shannon	17
Public relations	R. Middlebrook	19

Appendices

1. The Atmospheric Sciences Program organization chart; Members of Alberta Agricultures' Advisory Committee on Weather Modification; INTERA project personnel. 22
2. Rain experiments treatment summary 24
3. Daily summary of hailstorm and cloud seeding activities 20 June - 31 August 1984 25
4. Daily radar/computer tape logs 32
5. Project rainfall maps for June, July, August and Totals 35
6. Daily meteorological and storm hailfall summaries 36
7. Monthly summary of hail days and hail reports from 1974-1984; Daily log of maximum hail size reported; Hailcard format 55

Illustrations

		Page
Figure 1.	Atmospheric Sciences Program experiment areas	2
Figure 2.	A schematic representation of the 1984 hail experiments	3
Figure 3.	Cloud seeding logistics	9
Figure 4.	The 1984 hailstone collection network	14
Figure 5.	The 1984 precipitation measurement network	16
Figure 6.	Hailstorm tracks during 1984	20

Tables

Table 1.	1984 Hail and general thunderstorm experiments summary	4
Table 2.	1984 Rain experiments summary	6
Table 3.	Daily summary of flight information and plume tracing encounters	8
Table 4.	Seeding aircraft flare systems, 1984 Alberta Hail Project	9
Table 5.	Summary of INTERA aircraft operations, 6 June to 31 August 1984	10
Table 6.	Summary of aircraft cloud seeding operations, 20 June — 31 August 1984	11
Table 7.	Summary of aircraft missions 6 June to 31 August 1984	11
Table 8.	Daily summary of hailstone samples collected from the hailstone network during 1984	13
Table 9.	Definition of Convective Day Categories	18
Table 10.	Verification of forecast CDC categories, 20 June to 31 August 1984	18
Table 11.	Hail/no hail forecast verification, 1984	18
Table 12.	Summary of rawinsonde and airsonde releases during 1984	19

Introduction

With hail losses at $100 million annually, and insufficient water supplies in some parts of Alberta, the Alberta Research Council's Atmospheric Sciences Program is assessing and developing ways to alleviate these losses through the potential of weather modification.

The program emphasizes studies in cloud physics and meteorological processes with experiments in hail suppression, rain and snow augmentation. The Program goal is to provide the Government of Alberta with specific guidelines on conducting cost/benefit studies of certain types of weather modification within the Province.

The Alberta Hail Project (AHP), which provides the mechanism for the various experiments to meet their stated objectives and goals, is a comprehensive weather modification research program of the Government of Alberta. The Alberta Research Council (ARC), on behalf of Alberta Agriculture (the principle funding agency), acts as the central management and research agency for weather modification activities in Alberta. Guidance to both agencies is provided by Agriculture's Advisory Committee on Weather Modification. The Atmospheric Sciences Department of ARC is responsible for design and implementation of the overall Atmospheric Sciences Program. The Department's organizational chart and the members of the Advisory Committee are shown in Appendix I.

The Program is organized into two major projects, Weather Modification and Applications. These projects are in turn divided into sub-projects, some of which are further divided into specfic experiments. These experiments (hail, rain, plume tracing, lightning) that were conducted during the 1984 field season as well as activities of the various field operations are discussed in this report.

The AHP also includes an aircraft cloud seeding component operated under contract to INTERA Technologies Ltd. An independent cloud seeding program using ground-based silver iodide generators operated by I.P. Krick Associates of Canada Ltd, is operated in an area south of Calgary.

The AHP's principal target area of 48,000 km^2 is centered on the radar site located at the Red Deer Industrial Airport (Figure 1).

Field experiments

Hail

Preliminary cloud physics studies of cloud turrets in the new growth zone of Alberta hailstorms suggest that these cloud turrets (feeder clouds) provide a major source of hailstone embryos for the storm. The opportunity to alter natural hail growth processes through cloud seeding occurs in these clouds. The primary objective of the controlled seeding experiments is to document the effects of cloud seeding on hail growth by applying various treatments to individual cloud turrets in the new growth zone, and thus to ultimately determine the most effective treatment for suppressing hail. The underlying goals of the research aircraft studies are:

a) to obtain physical evidence of natural (untreated) precipitation formation processes within hailstorm feeder clouds,
b) to conduct experimental studies of feeder clouds in order to determine the effects of cloud seeding on these processes,
c) to determine the effectiveness of present operational seeding techniques,
d) to compare aircraft measurements of cloud hydrometeors size, shape and phase with S-band radar measurements of the same cloud,
e) to recommend optimal seeding strategies for hail suppression based on well documented cause and effect relationships determined from the case study evidence.

Experimental procedures

Controlled seeding experiments on hailstorms were designed to meet the primary objectives stated above. A schematic representation of the hail experiment procedures is shown in Figure 2. The experiments involve choosing individual cloud turrets in the new growth zone of hailstorms as test clouds according to characteristics measured by the research aircraft during pretreatment penetrations, and then applying an appropriate treatment (according to a random sequence) to the test cloud with a seeding aircraft. The effects of the treatment are then documented by repeated penetrations through the seeded cloud by the research aircraft. Once the seeded cloud becomes too intense to be penetrated, the growth and movement of its precipitation are documented by radar observations. In some cases, precipitation samples were collected at the ground by crews in storm chase

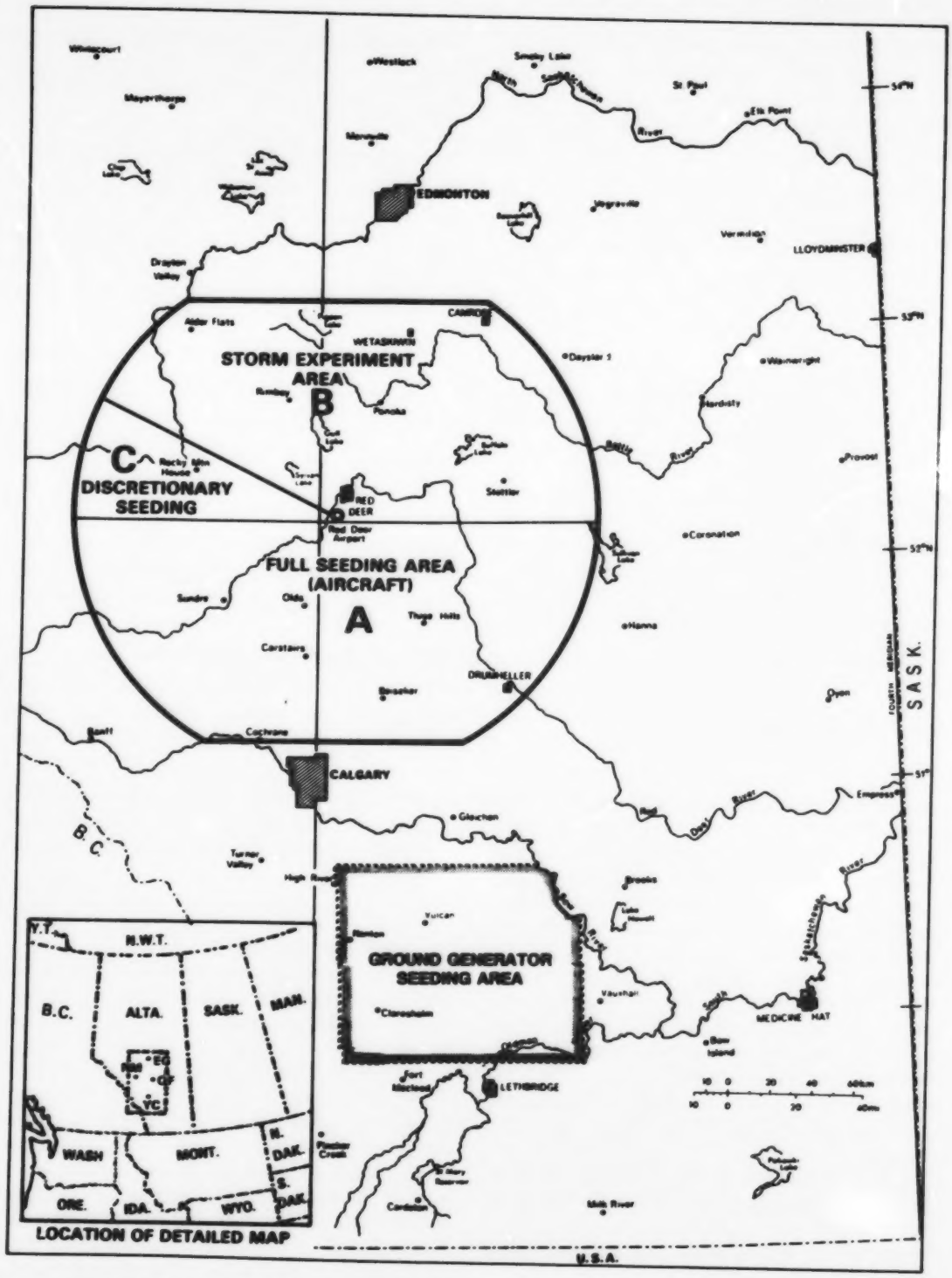


Figure 1. Atmospheric Sciences Program experiment areas. The area between Edmonton and Calgary is the principal target area of the Alberta Hail Project. The area south of Calgary is the I.P. Krick ground-based generator primary target area. (See section on cloud seeding for an explanation of areas A, B and C.)

vehicles to provide data for linking radar observations with hail on the ground. A more detailed description of the experimental procedures is in the Atmospheric Sciences Program Field Operations and Experiment Plan 1984 (page 11).

Preliminary results

Use of the research aircraft is summarized in Table I. There were eighteen flights for hail experiments and general thunderstorm studies, accounting for 49 hours of flight time. This time was divided between controlled seeding experiments and studies of natural or operationally seeded storms. Controlled seeding experiments were given the highest priority, but it was often not possible to perform them because 1) the storm was in the southern half of the project area and was already being operationally seeded, 2) storm structure was not appropriate for experimentation (storms occasionally did not have a feeding line of cumulus towers), and 3) feeder clouds did not pass the experimental criteria. In cases where controlled seeding experiments were not possible, general thunderstorm penetrations were performed. These penetrations provided observational data on natural hail formation processes and on the effects of operational seeding. Clearly defined seeding signatures (high concentrations of small, uniform-sized crystals) were detected by the research aircraft in some of the experiments. Cloud penetrations were possible for as long as approximately twenty minutes after treatment. Thereafter, the test cloud was usually too intense to safely allow additional cloud passes.

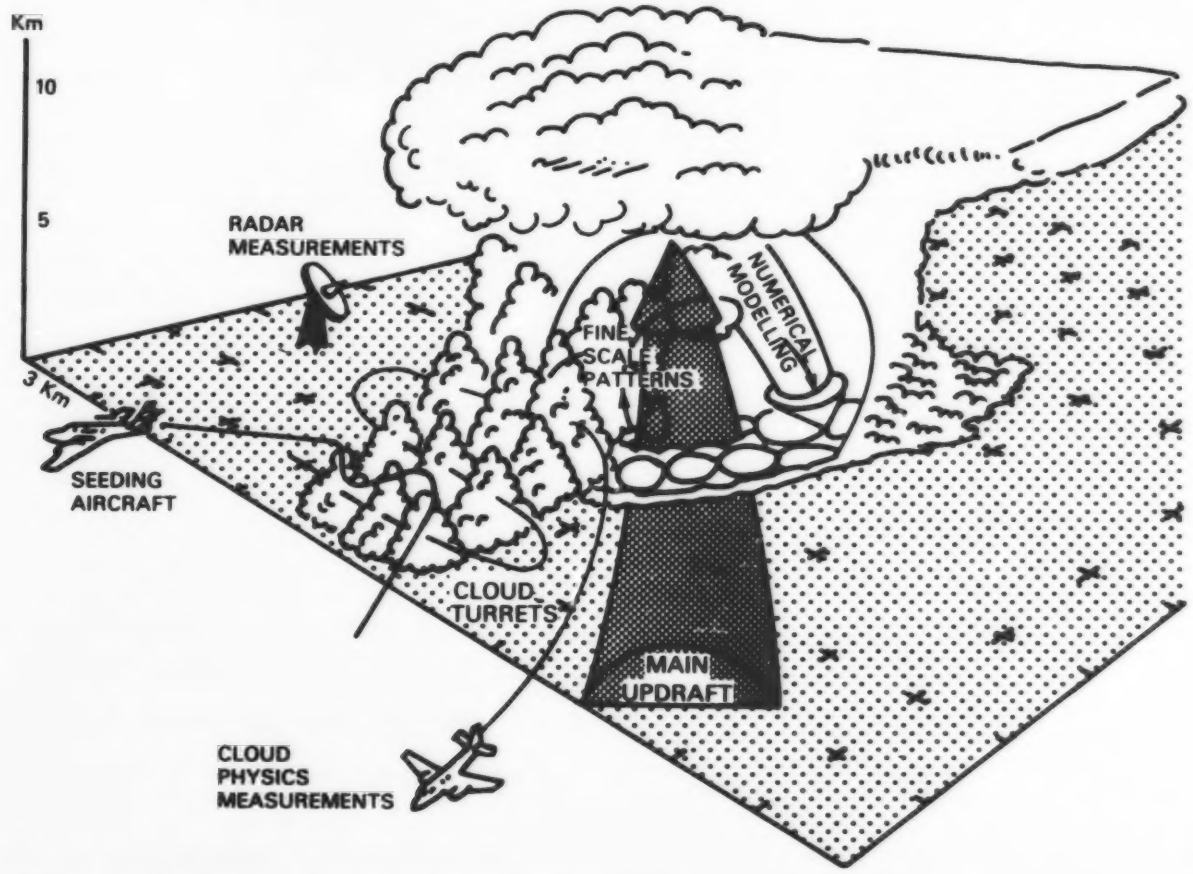


Figure 2. A schematic representation of the 1984 hail experiment. Seedability of cloud turrets in the new growth region of a hailstorm is determined during penetrations by the cloud physics aircraft. Repeated passes are made through the cloud turrets to document the growth and concentrations of ice crystals. Fine-scale radar reflectivity patterns are tracked, and subsequent hail growth is calculated using numerical models.

Table 1. 1984 Hail and general thunderstorm experiments summary

Date 1984	Takeoff (UTC)	Landing (UTC)	Duration (Hrs)	Number of Clouds	Number of Controlled Experiments	Number of Penetrations	Rime Samples ARC	Rime Samples DRI
June 15	2404	0157	1.9	1	0	6		
June 24	0016	0316	3.0	5	1	18		
June 25	2143	2433	2.8	4	1	9		
July 4	2139	0119	3.7	2	0	7	3	
July 5	2229	0059	2.5	2	1	9	4	
July 11	2240	0201	3.3	1	0	12	6	
July 12	2312	0124	2.2	3	1	10	5	
July 17	2329	0241	3.2	4	2	13	6	
July 19	2404	0149	1.8	1	1	6	2	
July 26	2135	2248	1.2	1	0	1	0	
July 28	2206	0155	3.8	11	2	21	6	
July 30	2138	2437	3.0	5	1	14	6	
Aug. 5	2320	0307	3.8	12	3	37	10	11
Aug. 6	2216	0222	4.1	12	3	27	12	14
Aug. 10	2123	2332	2.1	2	0	12	3	6
Aug. 17	2108	2314	2.1	4	1	6	4	5
Aug. 18	2334	0134	2.0	3	1	8	6	7
Aug. 24	2020	2250	2.5	4	1	9	7	
TOTALS	18 flights		49.0 hrs	77 clouds	19 expts.	225 pens.	79	43

Cloud water samples

Cloud water rime samples were obtained in order to study the effectiveness of silver iodide cloud seeding and to provide background data on the cloud water chemistry of Alberta clouds. The samples were taken in supercooled cumulus using two different sampling devices on the research aircraft: the Alberta Research Council's rime rod (designated ARC), and the Desert Research Institute rime rod (DRI). A total of 231 rime samples were obtained, 89 DRI and 142 ARC. The number of rime samples obtained only during hail experiment flights is summarized in Table 1. Of the 142 ARC samples, a subset of 23 was selected for analysis by the DRI laboratory because the samples were obtained simultaneously with DRI samples, and some of the clouds were deliberately seeded with silver iodide. All of the DRI samples are being analyzed by the DRI laboratory, and the other 119 ARC rime samples are being analyzed by the ARC Analytical Chemistry Laboratory. The samples are analyzed for silver, chromium and calcium content, mass, pH, and ion concentration (ammonium, nitrate, and sulfate).

Rain

The primary objectives of the RAIN experiments are to document the processes of precipitation development in natural and seeded towering cumulus clouds and to determine the most effective treatment for rain augmentation.

For these experiments, the INTERA/Alberta Research Council instrumented cloud physics research aircraft (a Cessna 441 CONQUEST) leads a seeding aircraft (5 km behind and 150 m above) through an isolated towering cumulus cloud at −10°C, on a heading orthogonal to the environmental wind shear. The cloud is accepted for experimentation when the following criteria are met:

1) supercooled liquid water content (from Johnson-Williams probe) is in excess of 0.5 gm^{-3} for five consecutive seconds,
2) ice crystal concentration (from Particle Measuring Systems 2D-C probe shadow-OR signal) never exceeds one per litre for five consecutive seconds,
3) cloud top temperature is initially between −7°C and −15°C,
4) initial cloud penetration takes less than 100 sec.,
5) vertical air velocities are positive for five consecutive seconds,
6) no echo is detectable on the research aircraft radar (minimum detectable signal approximately 15 dBZ at 5 km).

If the cloud is accepted, the crew of the seeding aircraft opens an envelope specifying which of three randomly ordered treatments is to be applied. The seeding treatments include 1) droppable AgI flares (one 20 g flare every 250 m), 2) dry ice pellets (10 g per 100 m), and 3) placebo. Initially, the seeding forms a line of vertical plumes which merge into a seeding curtain. After applying the specified treatment, the seeding aircraft stands off to photograph the cloud while the research aircraft repeatedly penetrates the test cloud perpendicular to the first pass. Beginning eight minutes after seeding, successive penetrations are made at 300 m lower altitudes every three minutes. Throughout the experiment, the Project's S-band or C-band radar monitors precipitation development. The treatment which has been applied is known only by the crew of the seeding aircraft until after data analysis is completed.

This year, additional experiments using cloud base flares, had been planned, using cloud base flares, to simulate ground based seeding and to determine the feasibility of cloud base seeding to initiate the precipitation process but (unfortunately none carried out). In these experiments, both aircraft were to follow each other near cloud base and, when a suitable cloud is chosen, the research aircraft climbs to the −10°C level for the initial test penetration. The same criteria are used to accept the test cloud for experimentation. If the cloud is accepted, two base flares (wing-mounted 150 g AgI flares) are ignited simultaneously. The seeding aircraft then performs a racetrack seeding pattern on the upshear side of the cloud. While the treatment is being applied, the research aircraft makes penetrations parallel to the shear in the −7°C to −10°C region of the cloud, and continues to make penetrations in this region until a seeding signature is detected. Thereafter, successive penetrations are made at 300 m lower altitudes every three minutes.

During the 1984 field program, there were 76 clouds investigated for potential rain experiments on 19 days. Thirty four of these clouds were treated using the standard randomized cloud-top seeding instructions. Preliminary observations indicate that radar echoes were detected, either onboard the research aircraft radar or at the ground radar site, on seven days. Lists of experiment days, the treatment times and some preliminary observations are presented in Table 2 and Appendix 2.

Table 2. 1984 Rain experiments summary

Date 1984	Takeoff (UTC)	Landing	Duration (Hrs)	Clouds Penetrated	Clouds Treated	No. of Penetrations	Comments
June 13	2244	2428	1.7	4	3	15	Clouds short lived. No radar echoes observed. Seeding signature detected.
June 19	2228	2422	1.9	2	1	6	Seeding signature detected.
June 20	2350	2621	2.5	5	2	19	Seeding signature detected.
June 22	1923	2116	1.9	4	1	15	No radar coverage. Clouds short lived. Seeding signature detected.
June 29	2235	2433	2.0	1	1	4	Seeding signature detected. Strong shear aloft.
July 2	2101	2305	2.1	1	0	1	Too much ice.
July 4	2139	0119	3.7	3	2	15	2 cases were TRW studies. Seeding signature detected. Radar echo detected.
July 9	2027	2352	3.4	4	3	23	No video camera. Seeding signature detected Radar echo detected.
July 13	2114	2303	1.8	2	2	10	Clouds short-lived. No seeding signature detected. Cloud tops <15K.
July 17	2328	0242	3.2	1	1	4	Hail and rain experiments.
July 27	2249	2529	2.7	3	1	7	Seeding signature detected.
July 30	2138	2437	3.0	2	2	10	Radar echo detected.
August 3	2053	2417	3.4	15	1	28	Large drops observed.
August 4	2358	2615	2.3	2	2	25	Radar echo detected.
August 9	2300	2512	2.2	8	1	18	Cloud top specially seeded with 2 base flares. Radar echo detected.
August 13	1748	2139	3.9	5	4	35	Radar echo detected. One special seed
	2341	2535	1.9	4	1	11	2nd mission of the day.
August 14	2220	2501	2.7	6	4	27	Cloud tops warm (–4°C). Seeding signature detected.
August 20	1948	2136	1.8	1	1	10	Seeding signature detected.
August 25	2110	2305	1.9	3	1	8	Computer problems. Radar echo detected.

Plume tracing

Introduction

Under contract, Dr. J.A. Heimbach, Jr. of Montana State University, conducted a plume tracing study in the ground-based generator seeding area south of Calgary. The field season for the study was from 10 through 31 July.

Goals

The overall goal of the 1984 plume tracing was to contribute to the assessment of the ground-based cloud seeding technique. The specific goals to be addressed were:

a) conduct flux measurements of AgI from the ground-based generators,
b) investigate downwind AgI plume attributes,
c) compare the detection of coke and arc generator plumes to those from an AgI-NH_4I acetone burning Skyfire-type generator,
d) conduct flight patterns to determine dispersion rates of AgI over the target area, and
e) examine the frequency of AgI plume encounters beneath convective clouds.

Silver iodide generators

The IPK Corporation provided two types of generators for the ground-based project. The type having the highest output burned AgI-NaI impregnated coke. Here, two fuels were available providing burn rates of $15g^{-hr}$ and $30g^{-hr}$. Calibrations of this generator indicated efficiencies of 5×10^{10} to 5×10^{11} ice nuclei per gram AgI. A later examination of this generator by the CSU Cloud Physics Laboratory in 1983 showed a higher ice nuclei production rate. An electric arc type generator burned approximately 1 g AgI per hour (with an efficiency averaging about 10^{13} per gram AgI). Both types of generators were established at the Okotoks airport.

A modified Skyfire-type generator was assembled by Dr. Heimbach. This generator burns an AgI-NH_4I complex dissolved in acetone. The mixture is injected into a propane flame (and has an efficiency of 10^{13} to 5×10^{14} ice nuclei per gram AgI effective at –10°C). The mixture was a 2% AgI solution by weight.

Aircraft

A Beechcraft Baron B58, was instrumented with an NCAR ice nuclei counter, an 8 in. Hg venturi and an inverter. All necessary modifications were made, and a successful test flight was made on 16 July.

Airport facilities

The aircraft was hangared at the Okotoks Air Park, located approximately two miles northeast of the town of Okotoks. Office and shop space were made available in the same building.

NCAR ice nucleus counters

Two, National Center for Atmospheric Research ice nuclei counters were available for the project. One counter, belonging to Colorado State University, was mounted in the aircraft because of its slightly more compact size and condition.

The other counter, belonging to ARC, was used to document background counts. However, the counter had to be taken out of service due to a break in a glycol line causing a short in a switch.

Winds aloft

A pilot balloon wind observing site was established at the Okotoks airport. One PIBAL was released at mid morning and hourly releases were made during and preceding tracing operations. PIBAL data were immediately worked up on an HP41CX calculator programmed for the purpose.

Data recording

All data were recorded by hand and on a tape recorder which was transcribed immediately after each flight. The NCAR counter data were recorded on Rustrak recorders. The CSU counter had two Rustraks, an integrated output and a step recorder which would increment for each count or each ten counts. A summary of flight information and plume encounters is listed in Table 3.

Lightning

Research on forecasting of damaging lightning flashes from radar observations, funded by the Canadian Electrical Association, led to field observations of lightning at the Red Deer Airport. In late August, a lightning direction finder (DF) was installed and tested at the Red Deer Airport with the cooperation of staff from the Research Institute of Hydro-Quebec (IREQ). The DF, designed and built by IREQ, consists of two orthogonal loop antennae, a vertical whip antenna and the electronics for the gathering, analog to digital conversion, treatment and transmission of the digital data to the data processing facility. The DF responds to the electromagnetic signal generated by a lightning flash and, through its orthogonal antennae, determines the direction to the location of the lightning flash.

The antennae and electronic assembly were mounted on the roof of a hangar, 10.7 meters above ground. The output signals were transmitted to a DEC-11/44 computer. Data were successfully gathered on August 17 from 1627 to 1727 MDT. The software to display the lightning directions on CAPPI displays of radar echoes of storms was developed subsequently. The test demonstrated that such a system can be used to identify electrically active storms within radar range. It is planned to install a second DF in Edmonton next summer in order to obtain flash locations in real time.

Table 3. Daily summary of flight information and plume tracing encounters

Date 1984	Beechcraft Baron B58 Air Hours	Total Hours	Type of Plume Encounters* Coke	ARC	Uncertain	Skyfire	Aircraft Release
June 16	2.0	2.2				8	
18	1.8	2.0	6				
19	3.0	3.2	3		8		
20	3.1	3.3	6		6		
21	3.0	3.2			8	3	
23	1.5	1.7	5	1			
24	3.4	3.6	18				
25	2.1	2.4		1			
26	1.2	1.8				(Tracing mission scrubbed)	
27	3.9	4.7	2				12
28	3.2	3.4			5	9	
29	2.6	3.2			10		
31	2.0	2.2				11	
Total	32.8	36.9	40	2	37	31	12

*Plume encounters are defined as 5 or more counts over an interval of 1 minute.

Field operations

Cloud seeding

Introduction

The cloud seeding operations for the 1984 program were again conducted by INTERA Technologies Ltd. under contract with the Alberta Research Council (ARC). The 1984 program was similar in many ways to that of 1983. The primary operational seeding area remained unchanged, while research activities were again carried out in areas A, B and C of the project area (see Figure 1). The cloud seeding operational guidelines remained essentially unchanged from those of 1983. This year, the INTERA aircrew training course was conducted on 18 and 19 June, while the operational seeding period was 20 June through 31 August. The aircraft complement was again four operational seeders plus one aircraft designated as a research seeder.

Cloud seeding logistics and equipment

The cloud seeding logistics remained unchanged from those of recent years. The seeding technique utilized various devices to deliver artificial ice nuclei (silver iodide) into hailstorms. Droppable flares were used for cloud top seeding to inject seeding material into the new growth regions of hailstorms. End-burning flares or acetone generators were used to seed from below the cloud base along the upwind portion of the sub-cloud inflow and updraft region with the updraft carrying the seeding material upward into the storm (Figure 3).

The cloud seeding guidelines were essentially unchanged from recent years. All storms in area A exceeding 40 dBZ were to be seeded. No storms in area B were

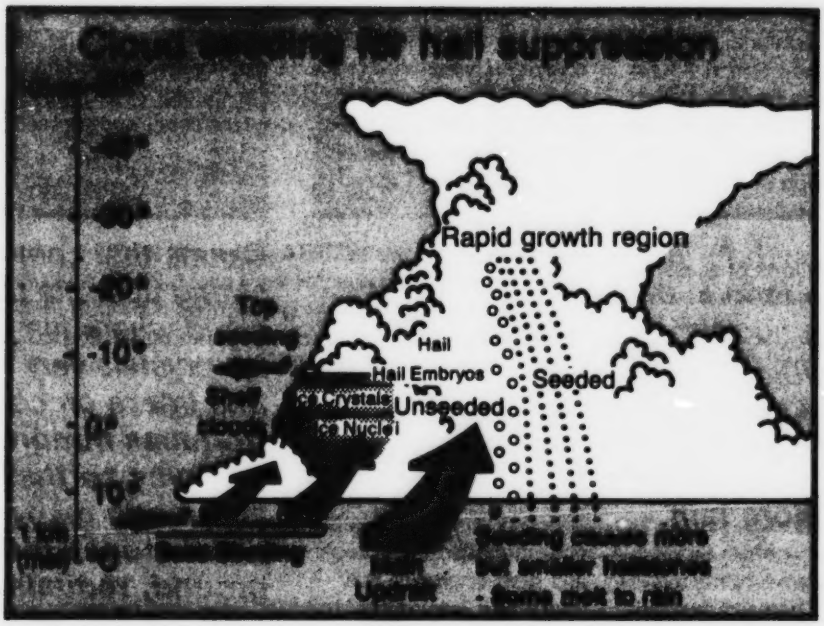


Figure 3. Operational cloud seeding logistics. Cloud top seeders drop a 20 g AgI flare every 250 m in the developing storm cells from an altitude equivalent to the −12°C level. Cloud base seeders burn a wing-mounted, 150 g flare below the base of the developing shelf cloud.

to be seeded, while those in area C could be seeded at the discretion of the ARC Operations Director. The research aircraft and reseach seeder could operate in any of the three areas (see Figure 1). When research was performed that might hinder operational seeding, the ARC Research Director could temporarily waive certain operational seeding requirements to facilitate research activities. This situation occurred several times during the course of the 1984 season. In each case, the transfer of control from operational seeding to research and back again was handled smoothly with minimum suspension of seeding coverage.

Unlike previous years, only one type of top flare system was used for cloud-top seeding in 1984. The Nuclei Engineering Incorporated TB1 20 g AgI pencil flares were released approximately once every five seconds (250 m). The use of pencil flares allowed greater dispersion of seeding material into hailstorms than was the case with the older, large top flares. Three operational seeders were equipped with the pencil flare systems in 1984, while one aircraft (FHRA) retained the large droppable system but used inserts allowing it to fire the pencil flares.
(See Table 4.)

Table 4. Seeding aircraft flare systems, 1984 Alberta Hail Project

Registration	Aircraft Type	Hailstop Number	Base Flare System	Top Flare System
C-FHRA	PAZT	1	Acetone	Pencil[1]
C-GRSJ	C310	2	End Burners	Pencil
C-GRKM	C310	3	Acetone	Pencil
C-GRST	C340	4	End Burners	Pencil
C-GBLB	C310	5	End Burners	Pencil[1]
C-GELL[2]	C411	6	End Burners	

1 Pencil flare inserts in large top system.
2 GELL was used in a temporary back-up capacity for one week in August.

For cloud base seeding, two types of systems were again used in 1984 (see Table 4). Two operational seeders were equipped with NEI 150 g AgI end-burning flares. Each aircraft carried 32 such flares and each flare had a burn time of four minutes. The other two operational seeders were equipped (for the fourth year) with acetone generators, which burned a 2% solution of AgI in acetone and output 2 g AgI/minute. Each acetone-equipped aircraft carried two generators, and each generator carried approximately five imperial gallons of solution, with a total possible burn time of about three hours.

The research seeder aircraft for the 1984 season was GBLB and was configured with pencil flares (in a large top rack), end burners, and an improved dry ice dispensing system.

Top and base seeding systems on all seeders were again reliable during 1984. Pencil flare and acetone systems were thoroughly checked and cleaned before installation at the beginning of operations. Improvements to the acetone burners included installation of heavy duty spark plugs to better ignite the acetone solution and replacement of corroded components. In addition, several of the burner cans were rebuilt.

The acetone solution storage, mixing and refueling system continued to work well in 1984. A flare technician was responsible for all aspects of the operation and maintenance of these flare systems.

Facilities

The permanent INTERA Red Deer hangar and laboratory complex again housed the seeding aircraft, the research aircraft and the support equipment and personnel. A new shed for storage and mixing of acetone was erected during the field season. A "ready room" with a "seeding hotline" was provided for the project's pilots.

One change to the control room equipment in the AHP operations center building was the replacement of the computer generated real time display system and hardware with an updated system and color displays (see Radar Section). The new system was under development during the field season.

Personnel

Appendix 1 lists the INTERA personnel involved in the 1984 program. This year, at least two, full-time INTERA aircraft maintenance engineers worked in support of the cloud seeding and research programs at all times.

Summary of cloud seeding operations

Table 5 summarizes all INTERA aircraft operations during the 1984 Alberta Hail Project. Included are research and test missions flown prior to commencement of operations on 20 June in addition to those flown during the operational period. The missions of the research aircraft are also shown. Table 6 outlines the cloud seeding operations beginning 20 June. Note that research aircraft and research seeder flights are not included in this table, nor are missions flown prior to 20 June. This year, pencil flare usage more than doubled compared to 1983 (6568 vs 2938) while the use of large top flares was discontinued. Acetone use was about 10% higher in 1984 than in 1983 and base flare usage was 30% lower. Each operational seeder averaged about 40 missions during the season and about 90 hr airtime during 73 operational days.

Appendix 3 contains a daily summary of hailstorms and cloud seeding activities. During the operational period (20 June to 31 August) there were 39 days with operational or research seeding (30 days with operational seeding only), 7 days with patrol only, and 27 days without seeding or patrol.

Table 5. Summary of INTERA aircraft operations, 6 June to 31 August 1984

Aircraft	Missions	Hours	Pencil Flares Dropped	Base Flares Burned	Acetone Burned (gal.)
HS1	48	97.8	1		47.4
HS2	51	105.1	2686	221	
HS3	30	80.7	1854		35.6
HS4	42	78.2	1982	121	
HS5	44	98.2	264	46	
HS6	5	9.0		4	
RS1	48	111.2			
TOTAL	268	580.2	6819	392	83.0

Table 6. Summary of aircraft cloud seeding operations, 20 June - 31 August 1984

Aircraft	Missions	Hours	Pencil Flares Dropped	Base Flares Burned	Acetone Burned (gal.)
HS1	44	94.8	1		47.4
HS2	47	101.7	2679	217	
HS3	30	80.7	1854		35.6
HS4	41	77.2	1982	121	
HS5[1]	6	7.1	52	9	
HS6	4	8.0		4	
TOTAL	172	369.5	6568	351	83.0

1 Research Seeder when used operationally

Table 7 presents a breakdown of aircraft missions by type. Flights include those prior to start of operations and those of the research aircraft and research seeder. Operational seeding and patrol missions amounted to 130 (299.2 hr), slightly less hours than 1983 (119 missions and 311.0 hr).

Table 7. Summary of aircraft missions, 6 June to 31 August 1984

	Seeding[1]	Patrol	Research[2]	Test	Training	Ferry	Support	ARC Total
Missions	126	42	40	23	14	20	3	268
Hours	351.1	65.2	101.9	25.6	21.6	10.8	4.0	580.2

[1] Includes Research Seeder
[2] Research aircraft only

Radar/Computers

Operating schedules and facilities were similar to those of the 1983 field program. In general, the C-band radar provided normal 24 hour surveillance data; the S-band radar provided information only during research activities.

During the month of August all radars were equipped with spark gaps across their respective magnetrons.

S-Band

In April, before the commencement of the 1984 field program, the S-Band antenna was lowered to the ground for inspection, to perform a series of antenna microwave measurements, and to install a new worm gear drive assembly.

While the feed horn was within easy reach, the cover plate was given a coating of resin to replace the worn away resin. A reapplication of resin to the feed horn cover appears to be necessary every five years.

Six weeks after installation of the new worm gear drive, an unusual sound commenced, diagnosed as worm gear run out. After consultation with the manufacturer, it was decided to proceed with standard operations and return the worm drive for refurbishing after completion of the field program.

To meet the demand for phase information at lower sensitivities, the S-Band phase chassis was redesigned, tested and demonstrated to be capable of providing valid phase data for RF levels of –100 dBm to –30 dBm.

The ATR cells were replaced to complete the refurbishing and the 3 phase, 10 Hp motor control relay system was completely replaced with new updated components.

The azimuth rotary joint failed in June, and was repaired with the assistance of the ARC machine shop utilizing commercially available parts to rebuild the internal plumbing and housing. The radar system was again operational 72 hours after failure.

The failure of a synchro transmitter on the polarization control circuitry prevented calibrations during the last week of the field program.

Between 1 May and 1 September, the S-Band system provided 490 hours of data.

C-Band

The coaxial magnetron modulator which had failed during the 1983 field program caused considerable concern for the 1984 field program. The complete modulator was redesigned, rebuild and fully tested with our coaxial magnetron at the manufacturer's plant. The magnetron and its modulator were reinstalled on 17 July and the radar returned to 24 hour surveillance and data recording mode. Calibration once a week (weather permitting) allowed maximum uninterrupted surveillance time for the Alberta Environment hydrology programs that ran simultaneously on the PDP 11/44 computer. Commencing 17 July, C-Band data were always recorded whenever S-Band data were not being recorded.

The C-Band system was in use from 22 June to 17 July with conventional magnetrons. However, because the frequency spectrums from these expired, conventional magnetrons were erratic, no data was recorded. The system was used only for surveillance during this time.

On 8 August, the modulator arced internally and the current monitoring circuit shorted to the modulator's case causing the loss of this minor facility. Additional modulator internal arcing problems commenced on 26 August. With slight adjustments to the transmitter's output power, the end of the field season was reached without a complete modulator failure. The modulator was returned to the manufacturer for repair in September.

The C-Band thyratron failed on August 26 and was replaced with a new unit.

Between 22 June and 1 September, the C-Band system provided 1065 hours of surveillance.

X-Band

Prior to the field program commencement, one transponder was returned from repair. A second transponder failed in June and was subsequently repaired and returned to service three weeks later. A third transponder was electrically destroyed by a power supply failure in a cloud seeding aircraft. The decision to proceed with repair is still outstanding, due to the high cost.

The refurbishing of the X-Band radar antenna has corrected impedance mismatch experienced in 1981. The system was run 2 dB below full power because of the low power rating of the present azimuth rotary joint. This rotary joint will be replaced with a high power unit as funds become available.

The passive TR limiter failed on 19 August and was replaced with an old active TR cell. The failure of the TR limiter was exhibited by a high insertion loss. The nominal life of a TR limiter is 1000 hours; the actual life of the installed limiter was 1,463 hours acquired over 4 years.

Between 1 May and 31 August, the X-Band system provided 309 hours of data.

Aircraft communications

The failure of AM radio coverage to extend beyond 20 mi was traced in early season to a failed antenna dipole. Repair of the dipole and repositioning of an FM yagi antenna corrected the pattern coverage somewhat. Problems with radio coverage were still evident, however, on rainy days. A complete check of the system will be done over the winter months.

New Installations

In keeping with the automation sytems being installed, the project acquired a new GPIB controllable spectrum analyzer, RF power meter, oscilloscope plug-ins, and an expandable frame equipped with a multi-function interface and an RF scanner. A microwave signal switching system and a control signal distribution system, both designed and built in-house, were installed. These systems interface the radars to the GPIB instruments. During the year, a new radar systems manual was completed.

Field computing radar/data processing

Three computers were used to record, display, and process radar data in 1984.

- The PDP-11/34 minicomputer (node AFPARC) in the radar building is connected to the C-Band radar, and the four channels of the S-Band radar, as well as the aircraft tracking system. This computer recorded data on magnetic tape as required, and provided S-Band data to other computers through the network.

- The PDP-11/44 minicomputer (node FLOARC) in the radar building is connected through a switch normally set to the C-Band radar or to one channel of the S-Band radar for backup. This computer routinely collected data from the C-Band radar, created CAPPIs (constant altitude maps), and transmitted this information in the form of rainfall rates to the Flow Forecasting Branch of Alberta Environment in Edmonton. This computer also controlled two LA120 printing terminals, providing a shared printing resource in the operations building.

- A Micro-11/23 microcomputer in the operations building provided color displays for aircraft control.

Two color monitors were connected to the single display generator. Radar data was obtained through the computer network from the computers described above, and an interactive program selected the data to be displayed. Problems with the data link between the radar building and the operations building severely limited the performance of the data transfer to this computer.

Other computers

- The research aircraft facility ground support computer(VAX-11/750) operated in building 38 as in 1983. Aircraft data Analysis software developed in Edmonton was installed on this system for reviewing data during the field season. The ARC standard graphics package(GSP) provided support for display terminals and the electro static plotter.

- A new VAX-11/730 computer was installed in July to record and process weather information received on teletype lines. This computer allowed several terminals to access the weather database.

All computers at the field site, except the research aircraft VAX and the VAX-11/730 were connected to the PDP-11/44, which was connected to the department's VAX-11/780 in Edmonton. The ARC Computing Department VAX-11/780 ran the meteorological data facility on a routine basis. Other operational programs were run on this computer or on the Atmospheric Sciences Department VAX-11/780.

Alphanumeric display terminals were installed in the administration building, the hail data office, and the weather office. General purpose terminals to access the Edmonton facility were available and connected to the 11/44.

Gandalf MLDS 122 mini modems were attached to all computer terminal communication circuits connected to the PIN 9103 multiplexer in building 38, eliminating electrical noise problems.

Operations Penhold/Edmonton

Four channel S-Band data were recorded on 366 tapes representing 377 hours on 56 days.

One channel C-Band data were recorded on 224 tapes representing 777 hours on 54 days.

Tapes were transferred to Edmonton via ASD personnel and other data were automatically transferred over the computer network at 0100 hours each day to arrive in Edmonton for timely analysis. Calibration files were plotted and checked daily. Radar logs were printed routinely to assist the scientists in evaluating the data. Aircraft logs and maximum reflectivity maps were stored on-line for analysis during the summer. The daily radar and computer tape logs are listed in Appendix 4.

Hailstone network

A network of 653 volunteer-operated stations was established within a 13,400 km² area of Red Deer (Figure 4) from 20 June to 15 August to collect time-integrated hailstone samples from the ground. The network was set-up similar to previous years with one summer student assigned to this project (on a half-time basis) to pick up the samples from the network, as compared to 4 or 5 in previous summers. This arrangement was less effective than originally anticipated. A backlog of uncollected samples resulted and eventually several ARC personnel were asked to assist in the collection. The time delay in picking up the samples resulted in many samples being of useless quality. It is recommended that hailstone samples be picked-up as soon as possible (within a week of the hailfall), especially for hailstorms of particular interest. Also, at least one person should be dedicated full time so as to effectively maintain a network of this size.

In total, 157 samples (from 25 hail days) were obtained from the volunteers and these are listed by date in Table 8. The hail samples collected will be analyzed for crystal structure and embryo type.

Table 8. Daily summary of hailstone samples collected from the hailstone network during 1984

Date 1984	Network Samples	Date 1984	Network Samples
May 20	1	July 12	7
May 24	1	July 13	1
June 13	1	July 19	1
June 16	7	July 20	3
June 17	5	July 21	13
June 18	20	July 24	1
June 19	4	July 28	5
June 22	2	July 29	1
June 25	10	Aug 5	8
June 26	1	Aug 6	44
June 29	3	Aug 11	4
July 5	2	Aug 13	5
July 6	7		
		TOTAL	157

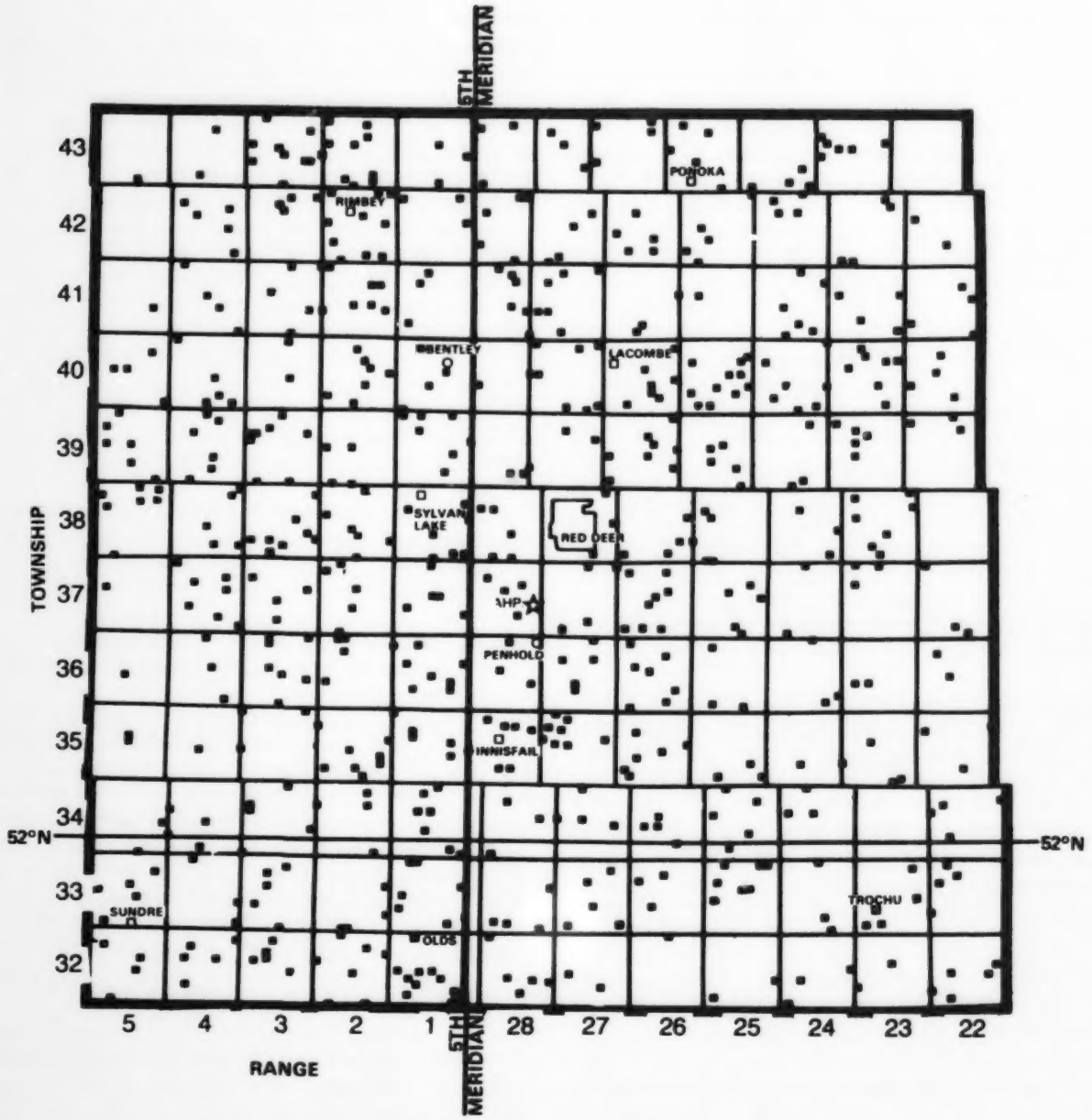


Figure 4. The 1984 Hailstone Collection Network. The network consisted of 653 volunteer operated stations within a 13,400 km² area.

Precipitation measurement network

A volunteer-operated precipitation measuring network of 635 stations was established over a 33,700 km² area in the project (Figure 5) to record daily rainfall accumulations. This is the tenth consecutive year that the network has been operational in the same geographical region, comprising a large database of summer precipitation information for central Alberta. The majority of the network (594 stations) was set up in May and maintained from 1 June to 1 September with an additional 41 stations set up in June. These additional stations were asked to collect rainfall data from 1 July to 1 September. The response from the network was again excellent, with over 93 percent of the operators completing at least one monthly record and over 80 percent returning completed rainfall records for the three months.

The station operators were visited by one of three summer students and supplied with a wedge-type rain gauge, colour coded monthly rain records, postage paid envelopes for returning the records and a folder for storing the supplies and instructions. The operators were asked to read the rain gauge at 0800 MDT each day and record the amount of precipitation observed in the gauge (equivalent to a 24-hour accumulation). They were requested to indicate "NH" on the forms for the days when absent from their residence and, upon returning home to read and record the amount of precipitation that had accumulated in the gauge during their absence. At the end of each month, the operators were asked to mail the completed form to the project in the postage paid envelope.

The data collected from the network are summarized by the precipitation maps for June, July, August, and the three-month cumulative totals as presented in Appendix 5. The warm dry summer in 1984 has resulted in the total summer precipitation being below the 30 year average in the project area.

Many observers are interested in having a copy of the precipitation data at their location. With over 50 percent requesting copies in 1984, it is suggested that the monthly precipitation records in future years be printed on carbon-type forms. Thus, the volunteer can immediately retain a copy of a completed record for his/her file while mailing the original to the project. Use of this form would save on manpower and postal expenses.

In appreciation for collecting the rainfall data, operators were presented with travel coffee mugs bearing the project's logo.

Storm forecasting

Field Research

Storm Forecast research activities have for years been conducted along two parallel lines. The first approach uses existing knowledge or theory of convective storms and adapts these to statistical forecast techniques. From this, the Synoptic Index has gradually evolved and has now been successfully tested. However, while providing usable products, this research has contributed little to new scientific knowledge of the processes involved. A second approach involves experimental field research emphasising the interactions between scales of atmospheric motion, including those induced by topography, so important to Alberta weather.

Important but limited advances in both research areas were made during the past summer. A new Sc4 "advection" model (ASc4) was developed and tested during the summer, then implemented operationally by mid-August. The ASc4, used in conjunction with the Sc4, provides the added capability to objectively predict the location, size, and orientation of (convective) storm complex initiation. Further improvements are planned as software assistance becomes available.

For the experimental approach, the availability of the research aircraft on two major storm days (19 July and 06 August, both with capping inversions), allowed partial mapping of the formation and breakdown of a capping inversion, an important phenomena related to storm structure and interaction with its environment. While an inadequate number of balloon soundings were made during the two days, preliminary results indicate that the aircraft mapping was substantial enough to support the scale interaction hypothesis (see Strong, 1984a). A thorough field effort, involving six or more sounding sites, aircraft mapping, and GOES data analysis, is now necessary and planned for 1985 (LIMEX-85).

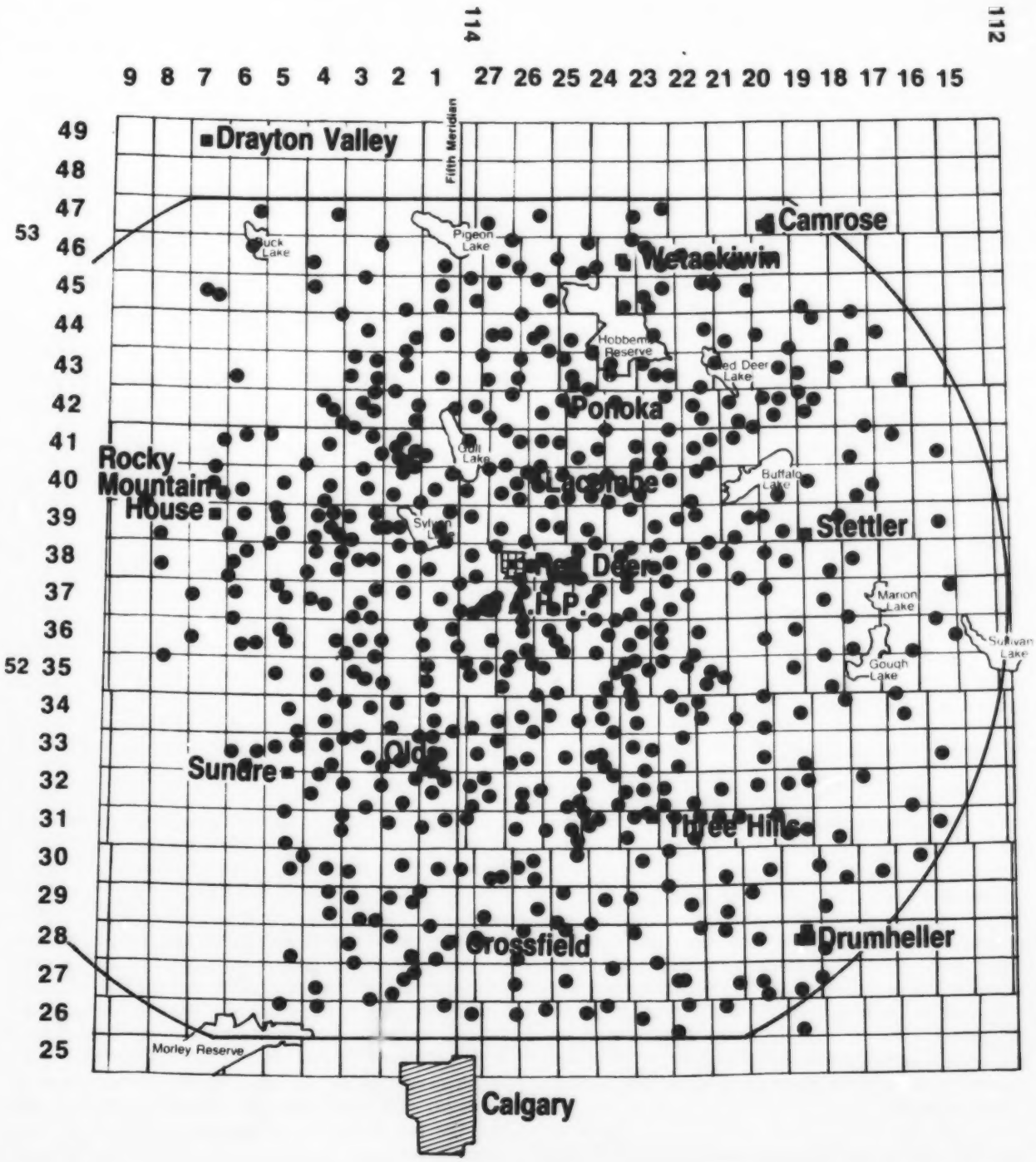


Figure 5. The 1984 precipitation measurement network. The 635 stations were established in a 33,700 km² area to record daily rainfall accumulations during June, July and August.

Weather office
The weather office was operational from 13 June to 31 August. Daily operations were from 0630 MDT to 2130 MDT.

Hard copy weather data were obtained from the Atmospheric Environment Service (AES) via two teletype lines and one weather facsimile circuit. The AES Alberta Weather Center provided forestry observations, the EGDEX forecast, and satellite imagery interpretations. The Project's weather office in turn supplied the Alberta Weather Center with daily forecast summaries and the Synoptic Index of Convection (Sc4) maps. Also, the Calgary (CYYC) and Red Deer (CAQF) rawinsonde soundings were sent on to the national weather circuit from an INFOMODE send/receive teletype.

A long-awaited Meteorological Data Facility (MDF) became operational in late July in the weather office. The arrival of the DEC VAX 11/730 computer eliminated the need to remotely access the MDF in Edmonton, which proved cumbersome and slow particularly during operations. An additional communications line was installed to provide weather data to the computer.

A UNIFAX II satellite recorder was ordered from United Press International but was not available for the summer field program. This machine produces high-resolution satellite imagery, an important tool to both operational forecasting and research.

Forecasting
Forecasting support for field operations covered the period 13 June to 31 August. Comprehensive briefings and forecast verifications are from 20 June to 31 August. As in the past, a mini-briefing was given at 0930 MDT to senior personnel to aid in daily planning. The comprehensive briefing was given at 1130 MDT with afternoon updates as required. An airsonde sounding (about 1200 MDT) provided useful additional information to the updates, although lack of available manpower precluded it from time to time.

The areal Sc4 was used operationally for the second season, and served as an invaluable aid in forecast decision-making. A contoured Sc4 map was presented at the weather briefings as guidance in prognosing storm formation regions and where convection would be most intense. Storm formation regions have been shown to correlate well with negative Sc4 advection. For this reason, an advection model was developed during the summer to produce an automated advection map of Sc4, mixing ratio, and theta-e.

Values of the Sc4 were subjectively modified by the forecaster to arrive at a forecast Convective Day Category (CDC — see Table 9) for the operations area. Tables 10 and 11 show the subjectively modified CDC and hail/no hail verifications respectively, and a comparison with 1983 values. The forecast CDC used in the verifications is that which is given at the 1130 MDT briefings. The improved forecast accuracy over 1983 can be attributed (in part) to better skill in interpreting the Sc4 field and to distinct differences in the weather regime between the two years. See Appendix 6 for the daily meteorological and storm hailfall summaries.

Upper-air operations
For the most part, the rawinsonde system remained unchanged from the previous year. The radiosonde computer program introduced last year was continually monitored and updated throughout the summer. Work is presently under way to adapt the airsonde output data to the radiosonde computer program to standardize the radiosonde and airsonde output parameters.

Twenty-two rawinsonde training ascents were completed by 8 June and operational soundings commenced at YC and QF on 11 June. Daily release times at both stations were set at 0615 and 1615 MDT.

The daily airsonde release for forecast update, initiated last summer, was reintroduced on an as required basis. Release time for the airsonde was tenuous depending on weather conditions and manpower availability. Most releases were made between 1200 and 1300 MDT.

A two-day field instrumentation program was performed 19 and 20 July in the foothills portion of the project area. Twenty soundings from three airsonde sites and the Rocky Mountain House upper-air station were augmented by the standard releases from YC and QF.

A total of 443 atmospheric soundings was accomplished this summer. Table 12 provides a break down of radiosonde and airsonde ascents.

Hailfall activity

Major storm days (100 reports or more) occurred on 3 days in the northern project area and on 5 days in the southern project area. The storms in the northern area on 6 July, 6 and 18 August accounted for 377 hail reports or 37 percent of the total reports from that area. The 801 hail reports from the storms on 6, 21, 28 July and 6, 19 August accounted for 61 percent of the total reports from the southern area.

Hail occurred on 45 days (hail day: one or more hail reports) in the project area, 4 percent below the 28 year

Table 9. Definition of AHP Convective Day Categories, valid from 1800 UTC (briefing time) to 1200 UTC the following morning.

CDC	Maximum intensity of convective weather
–3	No deep convection
–2	ACC, TCU, or CB at 2 or more surface weather stations
–1	Scattered showers (1 or 2 stations)
0	A thundershower without hail, or widespread showers
1	PEA or SHOT* maximum hail size
2	GRAPE* maximum hail size
3	WALNUT* maximum hail size
4	GOLFBALL* maximum hail size
5	LARGER THAN GOLFBALL* maximum hail size

*Two or more verifiable reports are required to qualify in each hail category.

Table 11. HAIL/NO HAIL forecast verification, 1984

OBSERVED	FORECAST: NO HAIL	FORECAST: HAIL
NO HAIL	37	4
HAIL	7	25

CORRECT HAIL DAYS FORECAST: 25 DAYS = 78.1% (72.2%)

CORRECT HAIL-NO HAIL STRATIFICATION: 62 DAYS = 84.9% (72.6%)

Figures in brackets are 1983 values.

Table 10. Verification of forecast CDC (subjectively modified Sc4) categories 20 June to 31 August 1984

OBSERVED CDC \ FORECAST CDC	-3	-2	-1	0	1	2	3	4	5	TOTALS
-3	3	5	1							9
-2	3	2	4	3		1				13
-1		2	3	2						7
0		1	5	3	1	2				12
1	1			3	3	2	2			11
2		1		1	3	4	2		1	12
3					2	2				4
4				1			3			4
5						1				1
TOTALS	7	11	13	13	9	12	7	0	1	73

NUMBER OF DAYS IN PERIOD:	73 DAYS
HAILDAYS IN PERIOD:	32 DAYS = 43.8% (49.3%)
CORRECT CATEGORY:	18 DAYS = 24.7% (27.4%)
CORRECT WITHIN ONE CATEGORY:	55 DAYS = 75.3% (63.0%)
CORRECT WITHIN TWO CATEGORIES:	67 DAYS = 91.8% (82.2%)

Figures in brackets are 1983 values
Dashed lines show forecasts accurate to within ± one category

Table 12. Summary of rawinsonde and airsonde releases during 1984

Rawinsondes

1984	CAQF	CYYC	CYRM	TOTAL
Training	14	8		22
Operations	166	166		332
Field instrumentation	1		6	7

Airsondes

1984	CAQF	LMW	JRB	LRC	TOTAL
Training	11				11
Operations	54				54
Field instrumentation		6	6	1	13
Display/demonstration	4				4
Total					443

LMW — Limestone Mountain West
JRB — James River Bridge
LRC — Limestone Mountain Ridge Center

CAQF — Red Deer Airport
CYYC — Calgary
CYRM — Rocky Mountain House

(1957-1984) average for the period 1 June through 30 September, and 2342 hail reports were received, 11 percent below average. In the northern area, hail was reported on 33 days, 15 percent below average. The 1021 hail reports received were 27 percent below average. In the southern area, hail was reported on 38 days (average), with 1321 hail reports received, 8 percent above average. Appendix 7 summarizes hail days and hail reports on a monthly basis.

Hail reporting cards combined with a project brochure were mailed 6 June to 71 946 farms in the province; 19 464 of these were inside the project area. During the reporting period 1 June to 30 September, 478 hail reports were received by mail. Figure 6 shows the hailswaths during the report period.

The hailcard format was similar to that of 1983. The format is shown in Appendix 7.

Telephone surveys were conducted on 36 days between 20 June to 31 August resulting in 1878 hail reports from inside the project area. Surveys of storms that extended outside the project area accounted for 11 hail reports.

Public relations

The Atmospheric Sciences field program located at the Red Deer Industrial Airport received increased attention over past years from both the news media and other Alberta agencies. There were many speaking engagements, newspaper articles and phone calls from the public as well as from the B.C. Ministry of Industry and Small Business and J. Fulton, a member of parliament from Ottawa. Highlights of public relation activites are as follows:

News media

In addition to the regular press releases, special interviews were requested by Alberta Agriculture "Call of the Land", CBC Toronto "Quirks and Quarks", CBC Toronto "Food Show", CBC Edmonton "Alberta Today", CKSW Swift Current, FM94 Swift Current, CBC Toronto "As It Happens", CJCY Medicine Hat, "Canada AM" Edmonton, Saskatoon Star, Saskatoon, CBC National News, CFAC Radio Calgary, CKRA Radio Edmonton, CKGY and CKRD Red Deer, Edmonton Journal, Alberta Report, Calgary Herald, Red Deer Advocate, Toronto Globe and Mail, Western Producer and the Olds Gazette.

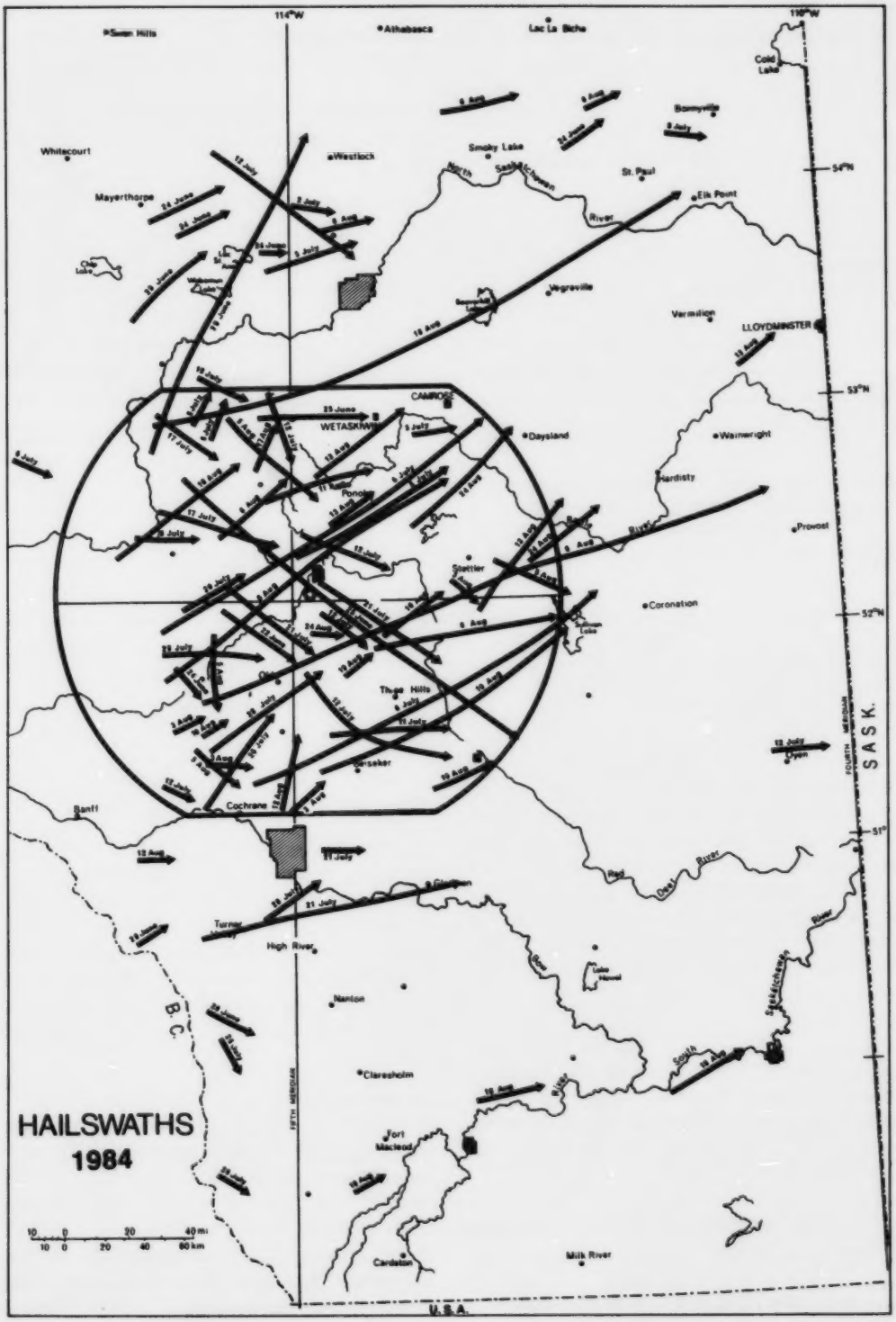


Figure 6. Hailstorm tracks during 1984. Hailswaths are determined by using two or more reports of pea or larger size hail. The arrows indicate approximate center line and direction of the storm. Some hailswaths have been supplemented by data from Alberta Hail and Crop Insurance Corporation.

ARC display
The ARC Display, which features considerable information on the Atmospheric Sciences Program was on display at various locations such as Edmonton, the Alberta Airshow in Red Deer and the Red Deer Agri-Trade Show. The Alberta Airshow included the research aircraft and a cloud seeding aircraft in the static display in addition to the ARC display in the trade show area.

Film
Alberta Agriculture recently produced a film called "The Weather Picture". This film contains excerpts showing the research operations of the Atmospheric Sciences program. The premier showing was on selected TV stations in the province from November 7 - 12, 1984. Six hundred and thirty one copies of the film advertisement were sent to the Precipitation Network farmers.

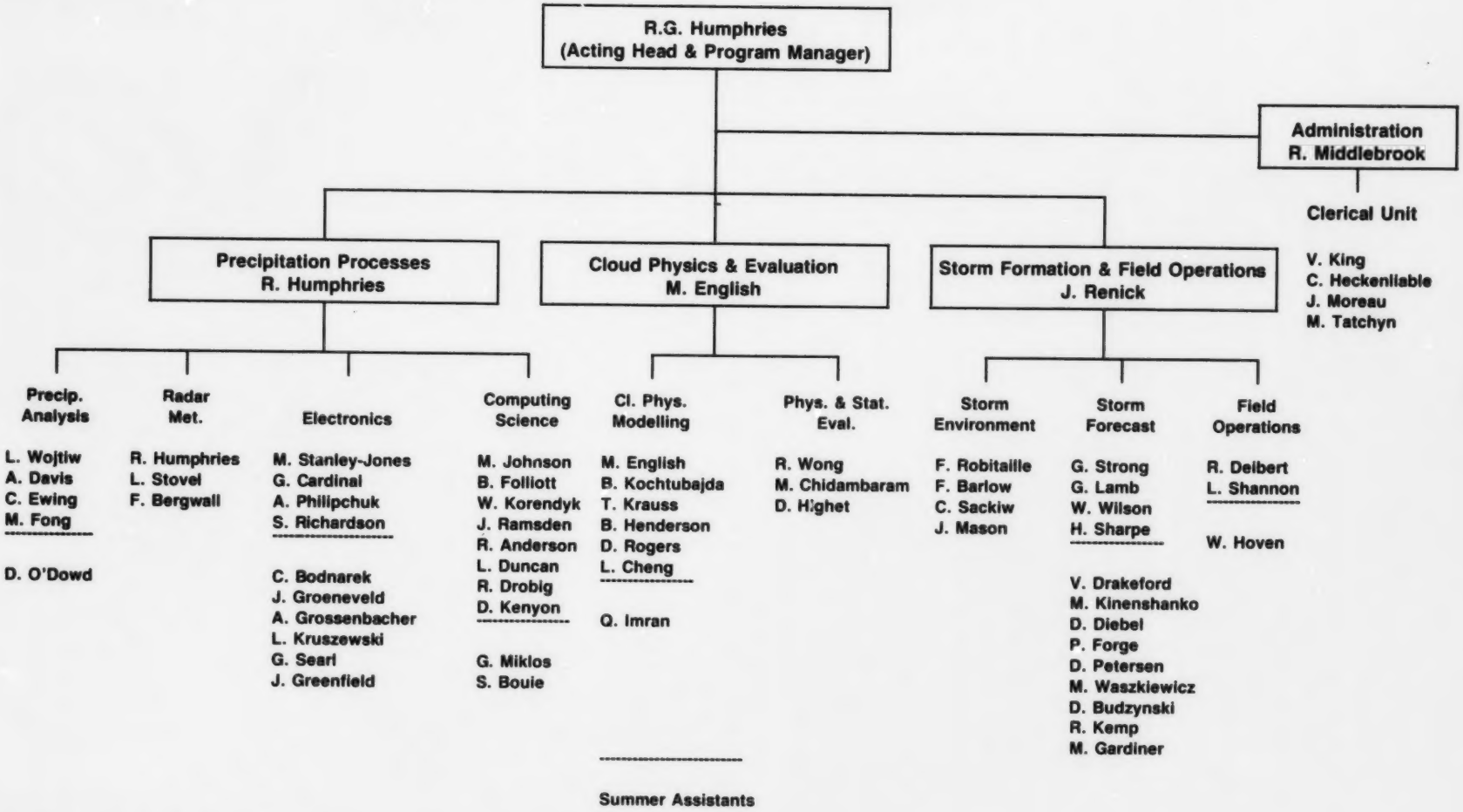
Tours
Numerous tours through the Weather Modification facilities were conducted during the summer field activities. These tours included the North American Interstate Weather Modification Council, District Agriculturalists from Central and Southern Alberta, Natural History Society, 4H, Retired Farmers of Alberta and a group from the Thorhild area.

Brochure
A new brochure outlining the activities of the Atmospheric Sciences Department was prepared for distribution prior to December 31, 1984. The brochure will be sent to precipitation network and hail sampling stations, legislative members, Universities, Federal and Provincial government agencies and interested private industry.

Code-a-phone
A code-a-phone was installed at the Red Deer offices of the Atmospheric Sciences Department in late August but installation was too late to be useful during the past summer. Plans for next summer include using the code-a-phone to provide information on current storm activity as well as the Atmospheric Environment Service forecast. This will allow the farm community and other interested people to call in for current storm information and research activities.

Also noteworthy, was the visit of Mr. Ping Wang from Beiging, Peoples' Republic of China. Under the Canada — China Human Development Training Program, Mr. Wang was assigned to the Radar Group for one month. During his brief stay, Mr. Wang was instructed in the operating and maintenance procedures of the field radars and was briefed on the overall operation of the ASD field research program.

ATMOSPHERIC SCIENCES DEPARTMENT



Appendix 1. Atmospheric Sciences Program Organization Chart.

Appendix 1. (continued) INTERA project personnel — 1984 Alberta Hail Project.

Chief Officer	B. L. Bullock	
Contract Supervisor	K. L. Grandia/Davison	
Radar Controllers	R. Rudolph	M. Oleskiw
	D. Rogerson	A. Stuart
	N. Dalezios	
Chief Pilot	P. Lens	
Research Seeder Pilot	W. Curtis	
Flare Technician	W. Cozens	
Aircrews	S. Holiday	M. Lawrysyn
	R. Rasmussen	L. Garand
	B. Loughlin	R. Gantner
	P. Grimsey	N. Carmichael
	J. Sears	J. Lancaster
Research Aircraft	G. Sanderson	P. Arsenault
	A. Schmidt	M. Oleskiw
Aircraft Maintenance	R. Mantay	W. DeJong
	K. Hashimoto	M. Sjerdal
	I. Herron	

Appendix 1. (continued) Alberta Agriculture's Advisory Committee on Weather Modification

CHAIRMAN

Mr. J. P. Christie, Farmer, Trochu

MEMBERS

Dr. J. P. Bowland, University of Alberta, Edmonton
Mr. R. W. Fisher, Farmer, Didsbury
Mr. L. K. Haney, Farmer, Picture Butte
Mr. H. E. Howe, Farmer, Swalwell
Mr. W. A. Jones, Farmer, Vulcan
Mr. T. G. Thurber, Farmer, Winfield
Mr. A. F. Wagner, Farmer, Lacombe

EX-OFFICIO MEMBERS

Dr. E. A. Babcock, Alberta Research Council, Edmonton
Dr. R. G. Humphries, Alberta Research Council, Edmonton
Dr. A. O. Olson, Alberta Agriculture, Edmonton
Mr. J. H. Renick, Alberta Research Council, Edmonton

SECRETARY

Mrs. D. Stewart, Alberta Agriculture, Three Hills

Appendix 2. 1984 Rain experiments treatment summary

Date 1984	Envelope	Treatment Number	Treatment Times (UTC)	Altitude (kft)	Heading (deg mag)	Cloud Base Measurements Pressure	Temperature
June 13	R-1	1	230512 - 230609	15.0	290	640 mb	–4.0°C
		2	233013 - 233050	14.7	070		
		3	235749 - 235819	14.7	090		
June 19	R-2	1	230030 - 230221	13.5	330	830	3.0
June 20	R-3	1	004353 - 004430	13.7	310	788	3.0
		2	011720 - 011729	13.7	020		
June 22	R-4	1	194940 - 195034	14.5	040	765	3.0
June 29	R-5	1	232340 - 232420	17.5	040		7.0
July 2						700	–2.9
July 4	R-6	1	222852 - 222912	16.5	315	753	4.8
		2	002251 - 002347	16.0	345		
July 9	R-7	1	210200 - 210244	14.0	315		–0.5
		2	214803 - 214830	14.0	340		
		3	222842 - 222930	14.0	135		
July 13	R-8	1	214445 - 214505	14.8	323	770	4.0
		2	222953 - 222959	15.1	350		
July 17	R-9	1	020107 - 020142	16.5	120	688	2.0
July 27	R-10	1	000645 - 000732	17.8	330	600	–1.0
July 30	R-11	1	235447 - 235511	18.0	125	770	10.3
		2	241110 - 241132	18.0	125		
August 3	R-12	1	231609 - 231638	18.5	315	812	13.6
August 4	R-13	1	242811 - 242824	18.0	245	698	5.4
		2	251557 - 251634	18.0	035	708	6.3
August 9	Special Seed		241512 - 241617	17.8	330		–5.5
August 13	R-14	1	181525 - 181552	15.3	265	708	0.8
	Special Seed		192235 - 192327	15.7	270		
		2	200508 - 200546	15.7	090	773	6.8
		3	205445 - 205535	16.0	100	837	10.8
	R-15	1	240752 - 240815	16.1	090		
August 14	R-16	1	224924-224926	13.0	360	765	5.0
		2	232242-232248	12.5	200		
		3	234215-234243	12.5	185		
	R-17	1	241933-242013	12.5	160		
August 20	R-18	1	201034-201055	14.0	205	709	–2.3
August 25	R-19	1	215944-220038	14.5	330	683	0.0

Appendix 3. Daily summary of hailstorms and cloud seeding activities, 20 June to 31 August 1984. Numbers in brackets are only operational cloud seeding totals; others are total flights and flares, including research.

WEATHER AND CLOUD SEEDING SUMMARIES

Date		Seeding and Patrol Flights	Pencil Flares	Base Flares	Acetone (gal.)
20 June	A line of cells developed in foothills west of Sundre beginning 1400 MDT tracking northeastward. Max tops to 25 K, reflectivities to 50 dBZ. Largely rain showers in southern area.	4(3)	–(–)	–(–)	1.4
21 June	Early overcast conditions began breaking up just before noon with scattered TCU developing. Midlevel cloud entered area mid-afternoon. Widespread showers in south and southeast during late afternoon and evening.	–(–)	–(–)	–(–)	—
22 June	Widespread thundershowers beginning early afternoon and continuing into evening. Cloud bases typically 7 K, max tops 20 K. Little organization. Weak to moderate cloud base inflow. Most activity near Drumheller, Bowden, Olds.	6(5)	7(–)	16(16)	3.7
23 June	Ridge building on continental divide. TCU developed in foothills and northwestern area. Storm motion about 270; bases 8-11 K; occasional tops to 25K. Scattered showers and virga in western half of project area.	–(–)	–(–)	–(–)	—
24 June	CU and AC in southern area throughout day with occasional TCU. Shortly after 1700 MDT, as temperature reached 25°C, TCU developed in Alder Flats-Lodgepole area moving eastward. Max tops 35 K, max reflectivity 45 dBZ. Main line of cells exited area 2100 MDT. One research seeder mission.	1(–)	4(–)	–(–)	—
25 June	First cells developed early afternoon Alder Flats area moving southeastward at 10 knots. These cells formed a large hailstorm which moved through Sylvan Lake — Penhold — Trochu area. Excellent inflow at cloud base, heavy rain. Storm exited area about 2000 MDT.	5(4)	189(179)	51(51)	—
26 June	No significant convection.	–(–)	–(–)	–(–)	—

Appendix 3. (continued)

27 June	No significant convection.	-(-)	-(-)	-(-)	—
28 June	Scattered CU.	-(-)	-(-)	-(-)	—
29 June	Cells began developing 1300 MDT south of Ancona in the foothills with later line formation from near Edson south to the James River Bridge. Storm motion 220/45 with tops to 45 K, max reflectivity 50 dBZ. The fabled "Chicken Plucker" storm of 1984.	3(2)	11(11)	-(-)	—
30 June	Scattered TCU in northwestern project area.	-(-)	-(-)	-(-)	—
1 July	Scattered TCU in north, CU in south.	-(-)	-(-)	-(-)	—
2 July	TCU developed early afternoon in northwest area. In late afternoon, TCU all quadrants with tops 15-17 K, max reflectivities 30 dBZ. Cell motion 270/20.	-(-)	-(-)	-(-)	—
3 July	Clear and warm.	-(-)	-(-)	-(-)	—
4 July	TCU developed mid-afternoon in foothills. Tops to 25 K, max reflectivity 55 dBZ. Cells tracking southwestward, northeastward, or southeastward depending on location — disorganized. Seeding targets generally iced-out with sporadic, weak inflows.	4(3)	28(-)	-(-)	0.7
5 July	First echo formed early afternoon in foothills west of Sundre. Tops 25 K, max reflectivities 50 dBZ, storm motion approximately 200/15. Most activity in Caroline — Penhold — Bowden area.	5(4)	482(482)	-(-)	5.0
6 July	First echo south of Rocky Mountain House late morning. Early afternoon line of cells formed extending from Edmonton south to Sundre with tops 28 K, max reflectivity 50 dBZ. Storm motion 250/20. Most activity in the Penhold — Big Valley — Three Hills region.	6(6)	185(185)	22(22)	3.6
7 July	Scattered CU, TCU.	-(-)	-(-)	-(-)	—
8 July	Scattered CU, TCU.	-(-)	-(-)	-(-)	—
9 July	Early afternoon cells in Three Hills and Elnora area. Tops to 27 K, max reflectivities 45 dBZ. Patrol and research missions only.	2(1)	27(-)	-(-)	—
10 July	Scattered TCU in southwestern area.	2(2)	-(-)	-(-)	—

Appendix 3. (continued)

11 July	Cells developed early afternoon in foothills west of Cremona, and later from Rocky Mountain House to Calgary. Initial motion 260/15, later 260/30. About 1700 MDT all cells began moving eastward. Embedded convection and much blowoff. Well-defined storm moved from Cremona to Munson region. Weak echo region penetrated by research aircraft. Cloud bases initially 9 K, rising to 15 K late evening. Tops to 35 K, max reflectivity greater than 50 dBZ. Operations terminated 2245 MDT due to power failure — no runway lights.	8(7)	458(458)	66(36)	3.4
12 July	First echos in foothills west of Calgary at noon. Later, major cells near Lodgepole (tops 40 K), 40 mi west of Cremona (tops 33 K), Strachan, Pine Lake, and in a line from Eckville south to Sundre. All motions due east. Cells suddenly deteriorated 1800 MDT into many small cells with showers associated. Targetting difficult.	9(8)	145(123)	18(18)	8.3
13 July	Small, short-lived line of cells moving 320/15 in southwest area. Max tops 18-20 K, deteriorating after 1500 MDT.	3(2)	-(-)	-(-)	—
14 July	Shallow CU in morning, clearing in afternoon.	-(-)	-(-)	-(-)	—
15 July	No significant convection in ridging conditions.	-(-)	-(-)	-(-)	—
16 July	No operations.	-(-)	-(-)	-(-)	—
17 July	First echo mid-afternoon near Rocky Mountain House tracking 275/20. Tops to 35 K, reflectivities 55 dBZ. Later development north of Rocky. Research missions only.	1(-)	7(-)	-(-)	—
18 July	Late afternoon development Strachan, Rocky Mountain House area tracking 260. Bases 15 K, disorganized.	1(1)	-(-)	-(-)	—
19 July	First echos 1430 MDT in foothills tracking 260/25. Rapid growth. Good top targets on southwest corner; good inflow southeast corner. Later, large echo mass in southern area with many embedded cells. Updrafts and downdrafts in close proximity. Widespread precipitation. Blowoff obscurring top seeders. Main cell area exited project area about 1930 MDT.	5(4)	296(273)	1(1)	5.8
20 July	Widespread showers southern area with some embedded convection. No seedable targets. Clearing late afternoon with low level inversion developing. Most convection south and east of Calgary.	2(2)	-(-)	-(-)	—

Appendix 3. (continued)

21 July	Overcast conditions breaking early afternoon. Many small, disorganized cells in clear air to west and northwest of Penhold. About 1530 MDT a line developed northwest of Sylvan Lake moving 290/20-25. Seeding commenced as it entered the southern area. Line was 90 mi long with good inflow and top targets, eventually extending from Dickson east to Hackett. A second line developed in it's lee about 2000 MDT but was disorganized.	6(6)	138(138)	45(45)	5.5
22 July	Scattered CU, clearing in afternoon.	–(–)	–(–)	–(–)	—
23 July	No significant convection.	–(–)	–(–)	–(–)	—
24 July	Scattered TCU, CU.	–(–)	–(–)	–(–)	—
25 July	No organized convection.	–(–)	–(–)	–(–)	—
26 July	Line of cells developed early afternoon in a north/south orientation in foothills west of Sundre. Occasional tops greater than 50 K, reflectivities to 65 dBZ. Motion 250/20. Most activity in Caroline, Innisfail, Didsbury, Sundre areas. Shelf cloud bases 12-15 K. Further development occurred after 1800 MDT behind this line with motion 180/30, tops 30 K. Declined rapidly.	5(4)	–(–)	23(23)	6.1
27 July	First echos late afternoon in foothills west and southwest of Caroline. Cell motion 220/15. Tops to 30 K, max reflectivity 40 dBZ, bases 12-13 K. Most activity southeast of Limestone Mountain.	4(3)	74(74)	1(1)	0.4
28 July	Cell development began 1300 MDT in a line along foothills west of Sundre. No movement until 2000 MDT when motion was 270/10. Large area of embedded cells with rapid vertical growth. Most activity west of Caroline, Sundre and Cremona. Max tops 38 K, reflectivities 55 dBZ.	7(6)	723(723)	36(36)	7.9
29 July	TCU in foothills. Little development or motion.	1(1)	–(–)	–(–)	—
30 July	First echos mid-afternoon Caroline area. By 1600 MDT tops 32 K, reflectivities 50 dBZ. Second region of activity east of Ponoka with tops 42 K, reflectivities to 55 dBZ.	3(2)	181(166)	–(–)	—
31 July	Early afternoon activity in foothills west of Caroline. Tops to 35 K, reflectivities to 50 dBZ.	1(1)	37(37)	–(–)	—
1 August	First echoes 1200 MDT in foothills west of Sundre. Initially, tops to 31 K with 35 dBZ reflectivities. Some seeding undertaken. Later activity west of project area tops to 40 K, reflectivities to 45 dBZ.	1(1)	29(29)	–(–)	—

Appendix 3. (continued)

2 August	First development near noon in foothills west of Sundre. By mid-afternoon extending well to northwest and southwest and scattered cells northwest of Rocky Mountain House. Late afternoon cells developed east and south of Calgary moving northward. Numerous small cells throughout area in late evening. Tops 33-36K, reflectivities to 50 dBZ but typically 40-45 dBZ.	1(1)	29(29)	–(–)	—
3 August	First echoes in northeastern project area, then in southeastern area. Motion 160/10. Tops to 38 K, 50 dBZ reflectivity. By mid-afternoon cells in this region were deteriorating and new development was beginning in foothills west of Sundre. Reflectivities to 60 dBZ, tops to 45 K. Bases dropped from 11 K to 7.5 K as storms matured and moved 210/15. Late activity also in Airdrie region.	6(5)	545(545)	21(21)	0.9
4 August	First echoes mid-afternoon in foothills west of Sundre. Motion eastward. Late afternoon development in Trochu-Three Hills area. Max tops 37 K, reflectivities 50 dBZ.	3(2)	340(336)	—	—
5 August	Rapid cloud development throughout southern project area beginning in foothills west of Sundre, then Bowden — Innisfail area, then Delburne — Big Valley region. Most activity in the Sundre — Bowden — Caroline area. Tops to 39 K, reflectivities 55 dBZ.	4(3)	661(661)	4(4)	4.3
6 August	Early afternoon development throughout foothills in southern area. Tops initially 30 K, later to 38 K, reflectivities to 55 dBZ. Most of activity in region from Caroline and Sundre east to Elnora and Trochu. Radio communication problems after 1800 MDT this day.	6(5)	1093(1063)	33(33)	6.2
7 August	Scattered CU and TCU.	–(–)	–(–)	–(–)	—
8 August	Scattered CU.	–(–)	–(–)	–(–)	—
9 August	Line of echos developed about 1500 MDT in foothills with motion 240/10. Several cells developed precipitation shafts. Much virga. Tops in area to 30 K, bases rising from 12 to 15 K. Diminishing early evening.	4(3)	–(–)	6(3)	—
10 August	Early afternoon activity beginning in foothills west of Calgary. Tops to 33 K, reflectivities 50 dBZ, motion 250/20. Top targets obscurred. Good inflow at base on southeast corner. Bases 12 K in shelf cloud.	4(3)	20(20)	16(16)	7.6

Appendix 3. (continued)

11 August	Initial development in foothills west of Rocky Mountain House. Tops near 30 K, reflectivities 45-50 dBZ, bases 14-15 K, tracking 260/20. Patrol only.	1(1)	–(–)	–(–)	—
12 August	First echos at noon near Sundre, and in early afternoon near Dogpound and Olds. Mid-afternoon activity in Acme — Drumheller regions. Tops to 25 K. Diminishing late afternoon.	6(6)	–(–)	1(1)	1.2
13 August	Late morning echos west of Sundre and Cremona. Later development near Caroline. Tops to 30 K. Mid-afternoon activity in Ponoka and Wetaskiwin area. Motion about 270/15.	4(2)	342(310)	–(–)	—
14 August	Late afternoon research activity on small storms in the region between Lacombe and Alder Flats. No operations.	1(–)	13(–)	–(–)	—
15 August	TCU mid-afternoon in foothills. Scattered CU. No operations.	–(–)	–(–)	–(–)	—
16 August	No significant convection.	–(–)	–(–)	–(–)	—
17 August	Mid-afternoon echos in a line of connected cells moving 215/20 in a north/south line from Lacombe to Edmonton. Occasional tops to 40 K, reflectivities greater than 60 dBZ. In south, storms developed in a line north of Calgary as ridge passed. Tops to 38 K, reflectivities to 50 dBZ. Several similar lines of lower intensity occurred throughout the day and into following night.	5(4)	1(–)	12(12)	2.0
18 August	Late afternoon individual cells developed about 50 km northwest of Drayton Valley moving 260/25 and gradually forming into lines. Tops above 40 K, reflectivities greater than 65 dBZ. High reflectivity maintained for several hours. Echos as far south as Caroline but most activity south and west of Edmonton.	2(1)	9(–)	–(–)	—
19 August	Early morning activity throughout southern area. Major activity late morning in Three Hills-Drumheller region. Echo motion about 260/30. Tops to 30 K, bases near 7 K. Later development in Lousana — Big Valley area east to Sullivan Lake. Diminishing mid-afternoon.	4(4)	–(–)	5(5)	3.1
20 August	No storms in project area. One research mission early afternoon.	1(–)	–(–)	–(–)	—

Appendix 3. (continued)

21 August	No significant convection.	–(–)	–(–)	–(–)	—
22 August	Some CU and TCU late evening in northwestern project area.	–(–)	1(1)	–(–)	—
23 August	Some shallow, disorganized convection mid-afternoon. In early evening cells developed southwest of Olds and extensively in south-eastern project area. Tops near 33 K, some reflectivities to 50 dBZ. Top targets obscurred, weak inflow.	3(3)	–(–)	4(4)	—
24 August	First echos near noon in foothills west of Sundre. Bases 9-12 K, tops to 35 K, reflectivities to 55 dBZ. Cells formed into a north/south line mid-afternoon extending from Sundre to west of Rimbey. Storm motion eastward, reaching Penhold about 1700 MDT. Later intensification of same complex near Fenn and Hackett and north through Stettler to Donalda with tops 30 K, reflectivities greater than 60 dBZ.	5(4)	347(347)	2(–)	5.8
25 August	A large number of small cells formed about 1400 MDT in a north/south line extending north of Three Hills with motion 270/30. Tops 25-28 K, bases 10-11 K, some reflectivities to 50 dBZ. Stabilization late afternoon.	3(2)	–(–)	–(–)	—
26 August	Mid-afternoon TCU in foothills. No seeding.	1(1)	–(–)	–(–)	—
27 August	First echos early afternoon northwest of Drayton Valley. Tops less than 20 K. Early evening patrol to foothills in southwest.	1(1)	–(–)	–(–)	—
28 August	No significant convection.	–(–)	–(–)	–(–)	—
29 August	Scattered TCU, CU southwest foothills.	–(–)	–(–)	–(–)	—
30 August	No significant convection.	–(–)	–(–)	–(–)	—
31 August	Mid-afternoon short-lived convective cells developed in Trochu-Elnora area. Tops 16-20 K, 30 dBZ reflectivities. Eastward motion.	–(–)	–(–)	–(–)	—

Appendix 4. Daily radar/computer tape logs

Date and times for which C-Band data were logged

22-JUN-84	13:15	20:09
23-JUN-84	13:36	18:49
29-JUN-84	13:18	17:30
	17:35	18:13
	19:05	22:45
	22:53	24:00
30-JUN-84	00:00	06:44
02-JUL-84	15:56	16:29
	16:34	17:43
06-JUL-84	10:12	13:25
	18:10	22:05
08-JUL-84	17:42	18:56
	22:14	24:00
09-JUL-84	00:00	00:02
	12:23	13:15
11-JUL-84	23:40	24:00
12-JUL-84	00:00	05:53
	05:57	10:50
13-JUL-84	04:08	10:40
	18:20	20:49
19-JUL-84	15:10	15:25
	20:47	24:00
20-JUL-84	00:00	01:20
	03:07	07:18
	12:39	17:13
	17:14	23:24
21-JUL-84	02:09	15:32
	15:43	15:53
	20:25	23:50
22-JUL-84	02:09	07:15
24-JUL-84	03:40	07:05
	07:12	15:31
	15:34	15:39
	19:41	24:00
25-JUL-84	00:00	00:28
	00:30	07:30
	07:42	24:00
26-JUL-84	00:00	01:15
	01:41	06:27
	06:39	09:41
	14:20	15:20
	20:21	24:00
27-JUL-84	00:00	00:58
	01:03	06:11
	06:37	11:22
	20:34	24:00
28-JUL-84	00:00	08:50
	10:29	13:09
	22:43	24:00
29-JUL-84	00:00	06:20
	06:39	09:07
	09:20	11:38
	19:48	24:00
30-JUL-84	00:00	00:28
	01:29	06:03
	06:40	09:11
	11:35	12:34
	12:40	13:40
	21:05	24:00
31-JUL-84	00:00	03:00
	03:01	05:54
	06:39	10:56
	12:15	12:44
	19:59	24:00
01-AUG-84	00:00	06:05
	06:38	09:14
	17:36	24:00
02-AUG-84	00:00	04:37
	04:43	06:25
	06:38	14:00
	22:35	24:00
03-AUG-84	00:00	06:21
	06:42	14:31
	19:35	24:00
04-AUG-84	00:00	06:23
	06:35	16:47
	20:53	24:00
05-AUG-84	00:00	01:49
	02:33	06:21
	07:06	10:54
	22:08	24:00
06-AUG-84	00:00	06:16
	06:40	13:56
	21:02	24:00
07-AUG-84	00:00	06:18
	06:45	24:00
08-AUG-84	00:00	00:34
	08:25	13:35
	18:12	24:00
09-AUG-84	00:00	06:22
	06:47	13:10
	15:18	16:14
	20:06	24:00
10-AUG-84	00:00	06:24
	06:30	09:30
	18:46	24:00
11-AUG-84	00:00	06:27
	06:45	10:05
	10:39	14:42
	20:44	24:00
12-AUG-84	00:00	01:25
	02:08	06:20
	06:38	12:06
	21:22	24:00

Appendix 4. (continued)

13-AUG-84	00:00	06:23
	06:45	10:13
	20:24	24:00
14-AUG-84	00:00	06:15
	06:40	12:58
	19:25	24:00
15-AUG-84	00:00	01:10
	01:13	06:24
	06:41	08:24
	08:51	24:00
16-AUG-84	00:00	06:24
	06:44	12:21
	18:00	24:00
17-AUG-84	00:00	06:24
	06:29	14:10
	19:07	24:00
18-AUG-84	00:00	06:23
	06:38	16:00
	19:46	24:00
19-AUG-84	00:00	02:20
	03:06	06:24
	06:37	09:00
	09:05	10:11
	10:12	12:44
	18:36	19:45
	19:47	24:00
20-AUG-84	00:00	06:20
	06:41	08:40
	08:55	09:20
	09:30	12:07
	19:00	24:00
21-AUG-84	00:00	06:15
	06:40	24:00
22-AUG-84	00:00	06:23
	06:41	17:19
	17:29	24:00
23-AUG-84	00:00	01:12
	01:13	06:20
	07:00	13:34
	14:40	15:45
	18:53	19:50
	21:42	22:08
	23:10	24:00
24-AUG-84	00:00	06:24
	06:42	13;09
	19:17	24:00
25-AUG-84	00:00	06:21
	06:40	14:00
	18:05	24:00
26-AUG-84	00:00	00:30
	01:19	06:17
	06:42	14:46
	20:09	21:38
27-AUG-84	15:50	19:50
	19:59	24:00
28-AUG-84	00:00	06:25
	06:45	10:12
	10:14	24:00
29-AUG-84	00:00	06:26
	06:42	24:00
30-AUG-84	00:00	06:27
	06:42	24:00
31-AUG-84	00:00	06:24
	06:44	18:04

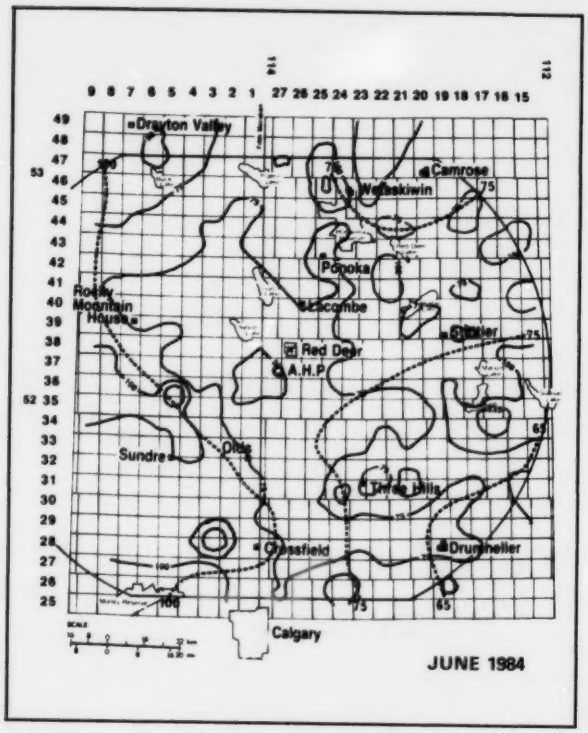
Date and times for which S-Band data were logged

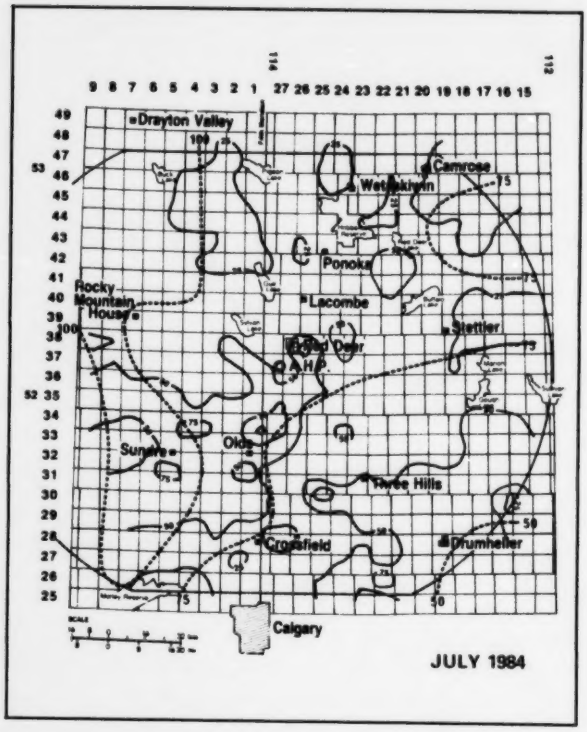
06-JUN-84	13:00	14:23
	14:29	14:45
13-JUN-84	13:02	17:16
	17:17	21:45
14-JUN-84	14:44	17:55
	18:04	21:07
15-JUN-84	11:14	11:56
	17:30	20:05
16-JUN-84	12:40	15:34
18-JUN-84	13:51	18:29
19-JUN-84	10:11	18:07
20-JUN-84	08:05	10:10
	13:43	20:32
21-JUN-84	09:25	11:19
	11:19	17:33
	21:36	24:00
22-JUN-84	00:00	01:58
	08:11	11:21
24-JUN-84	09:20	10:44
	10:44	16:10
	16:11	23:28
25-JUN-84	06:32	20:31
26-JUN-84	08:17	12:39
27-JUN-84	05:16	05:56

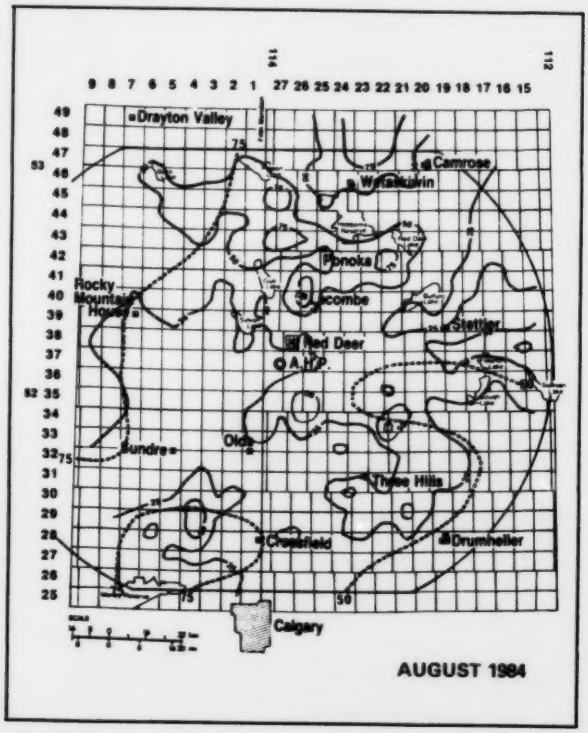
Appendix 4. (continued)

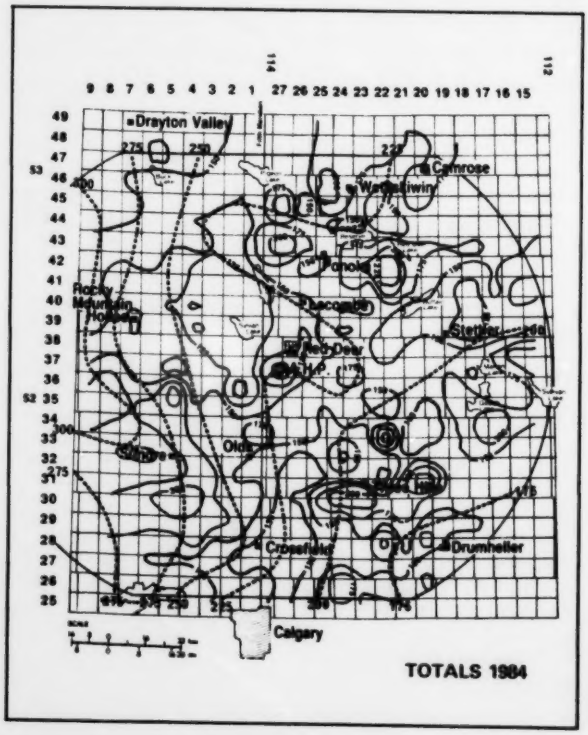
29-JUN-84	07:52	08:35
04-JUL-84	14:51	16:20
	16:25	17:57
	18:01	19:30
	19:48	21:11
	21:16	21:56
05-JUL-84	14:20	24:00
06-JUL-84	00:00	02:14
	13:27	16:50
	17:00	18:00
09-JUL-84	13:27	19:51
11-JUL-84	13:51	17:34
	17:42	22:50
12-JUL-84	11:02	17:00
	17:08	24:00
13-JUL-84	00:00	00:15
	00:19	01:56
	14:01	14:22
	14:26	18:18
17-JUL-84	16:32	20:00
	20:02	23:10
18-JUL-84	17:53	24:00
19-JUL-84	00:00	00:54
	15:41	20:39
20-JUL-84	07:25	12:37
21-JUL-84	15:35	15:41
	15:57	16:46
	16:55	20:23
26-JUL-84	15:20	20:19
27-JUL-84	11:16	21:31
28-JUL-84	13:14	22:43
29-JUL-84	12:06	16:29
	16:30	19:46
30-JUL-84	13:39	14:22
	15:53	18:09
	18:29	21:03
31-JUL-84	16:13	19:58
01-AUG-84	14:33	17:31
02-AUG-84	14:01	22:23
03-AUG-84	14:32	19:34
04-AUG-84	16:48	20:52
05-AUG-84	11:00	22:06
06-AUG-84	13:56	21:05
08-AUG-84	01:02	06:15
	06:41	08:15
	13:45	18:10
09-AUG-84	16:15	20:05
10-AUG-84	09:30	13:15
	13:50	18:45
11-AUG-84	14:45	15:12
	16:10	20:40
12-AUG-84	12:07	12:37
	12:51	13:27
	13:37	21:21
13-AUG-84	10:13	20:22
14-AUG-84	13:30	19:23
16-AUG-84	12:22	17:58
17-AUG-84	14:10	19:06
18-AUG-84	16:06	19:44
19-AUG-84	12:56	14:38
	14:40	18:35
20-AUG-84	12:48	19:00
23-AUG-84	14:00	14:38
	15:46	18:45
	19:50	23:03
24-AUG-84	13:10	19:15
25-AUG-84	14:00	18:03
26-AUG-84	14:56	20:07
	21:15	24:00
27-AUG-84	00:00	00:48
	01:36	06:26
	06:40	15:44

Appendix 5. Project rainfall maps









The contour lines are rainfall amounts in mm. The dotted lines are long-term climatological averages.

Appendix 6. Daily meteorological and storm hailfall summaries

Appendix 6 covers all days during the summer program with either:

a) 10 or more hail reports received,
b) grape-sized hail reported,
c) cloud seeding activity (research included), or
d) research aircraft flights.

Data for each day includes:

a) a 500 mb height and thickness or vorticity analysis for 1800 MDT (2400Z),
b) a representative upper-air sounding (tephigram) with hodograph,
c) a hailfall and cloud seeding summary map.

The 500 mb maps are reproduced from official AES microfilm records or facsimile charts (for days when film was not available). Solid isopleths on the analysis are height contours at 60 m intervals, and dashed isopleths are 1000-500 mb thickness at 60 m intervals.

Soundings for either CYYC, CAQF or CWEG were chosen with due respect to development areas, motion and timing of the most significant storm cells. These show dry bulb (solid line) and dew point (broken line) temperatures, and the moist adiabat that best represents the storms for that day. The short horizontal bar represents cloud base. Each moist adiabat was derived from values of maximum temperature and mixing ratio (labelled at the base of the sounding) judged to be the most representative for the storm area, and not necessarily at the radiosonde station itself. Mixing ratios (to the nearest 0.5 g kg^{-1}) were obtained by averaging over 50 mb or less in the mixing layer. Heights given are with reference to MSL.

Legend:

general hailswath areas

walnut and larger hail areas

operational cloud seeding envelope

research cloud seeding envelope

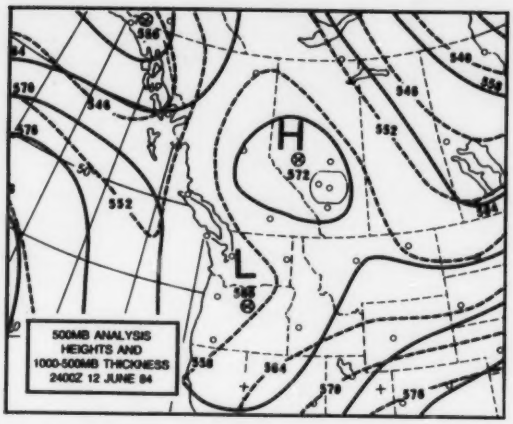
Storm dates include:

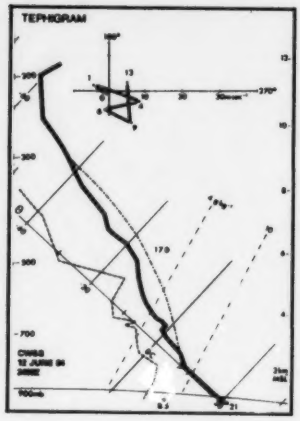
June: 12, 13, 15, 16, 17, 18, 19, 20, 22, 24, 25, 29

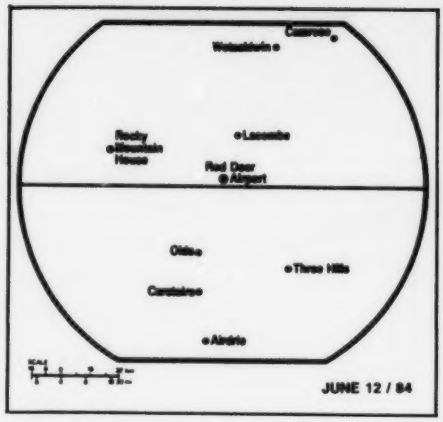
July: 4, 5, 6, 9, 11, 12, 13, 17, 18, 19, 20, 21, 22, 26, 27, 28, 29, 30, 31,

August: 1, 2, 3, 4, 5, 6, 9, 10, 11, 12, 13, 14, 17, 18, 19, 20, 23, 24, 25, 26, 27, 28, 30

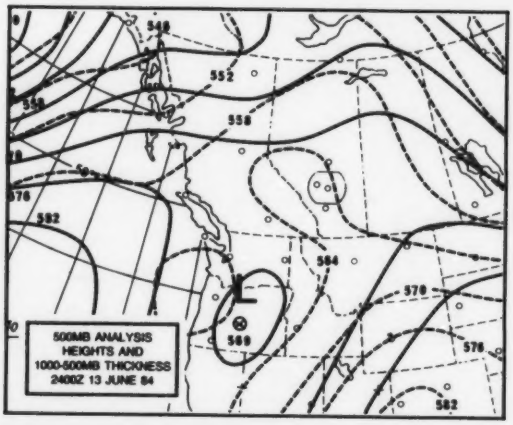
Appendix 6. (continued)

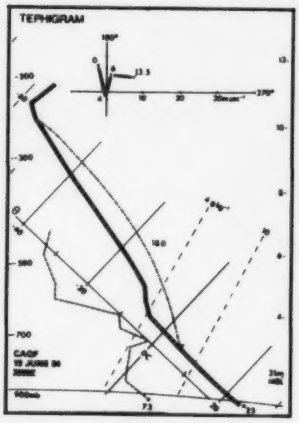


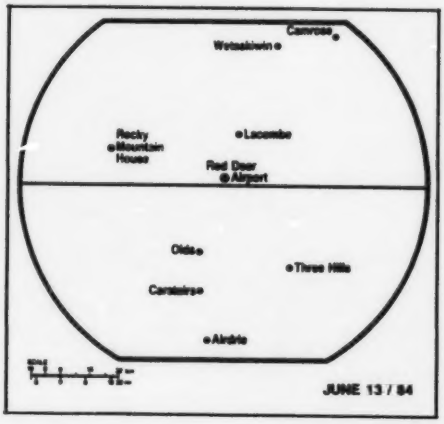




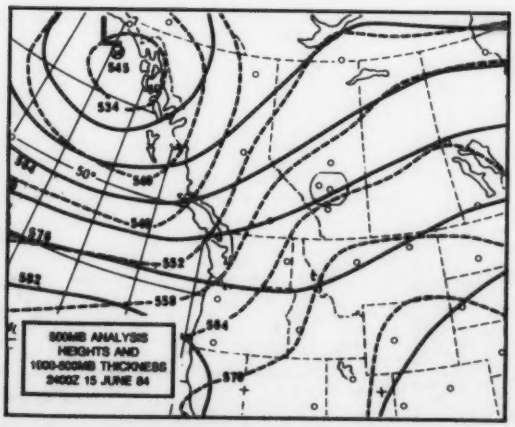
12 JUNE 84

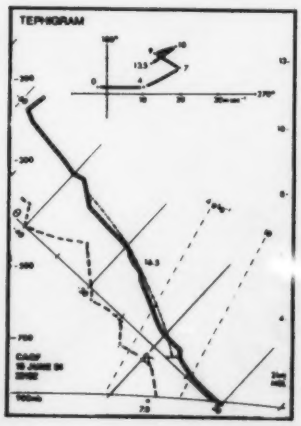


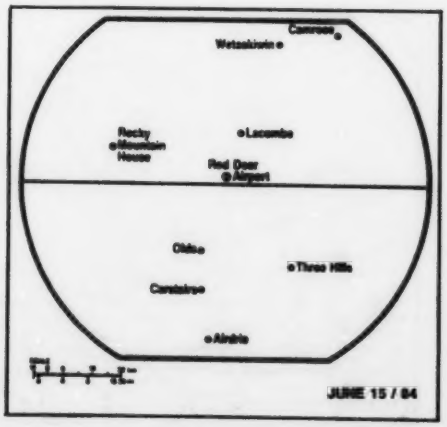




13 JUNE 84

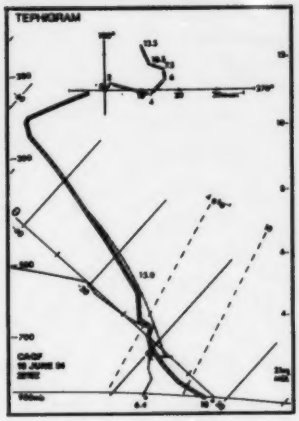


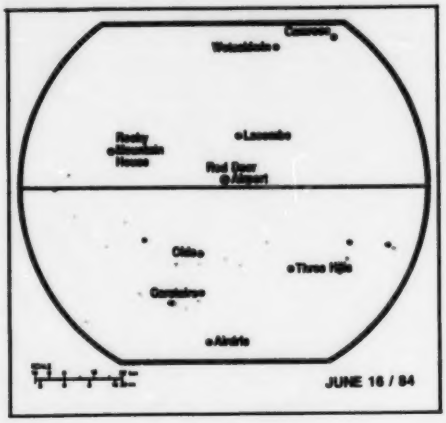




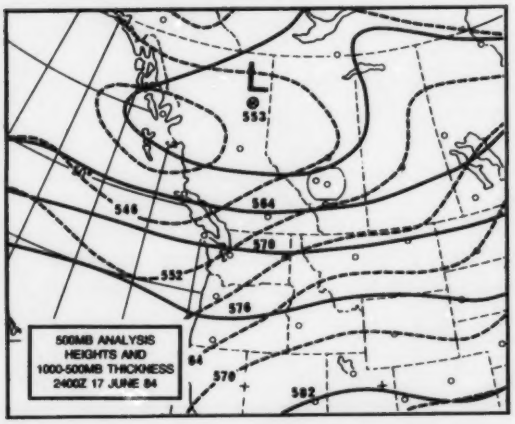
15 JUNE 84

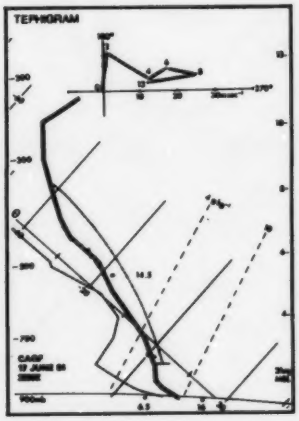
Appendix 6. (continued)

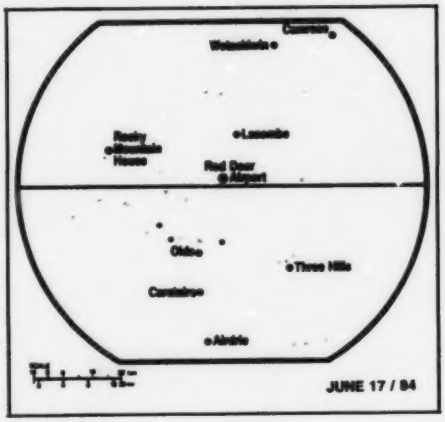




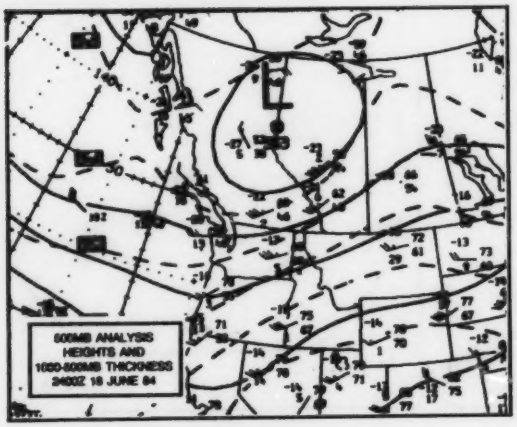
16 JUNE 84

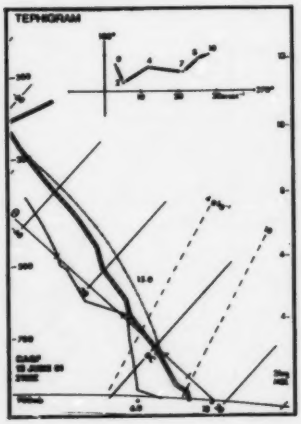


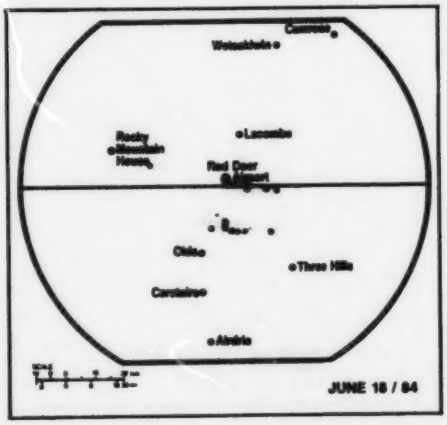




17 JUNE 84

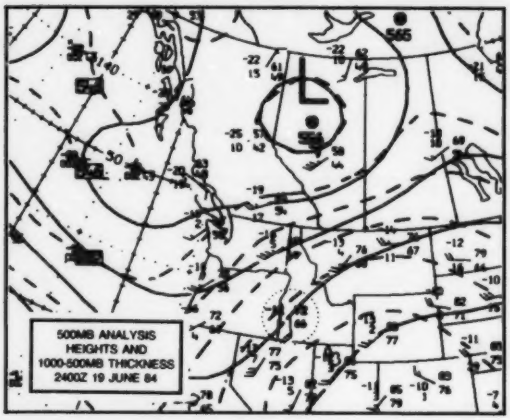


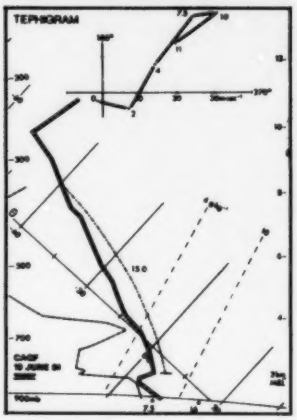


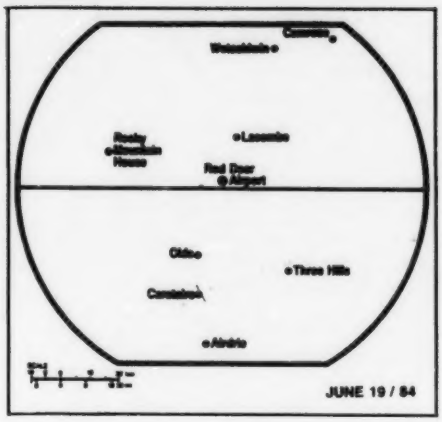


18 JUNE 84

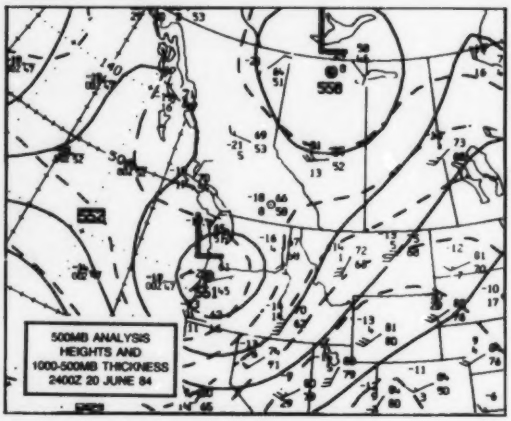
Appendix 6. (continued)

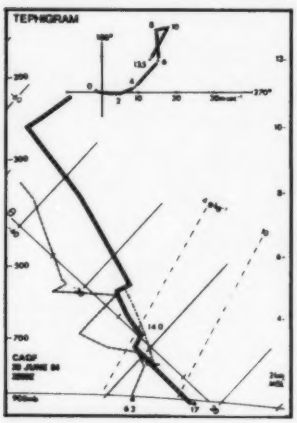


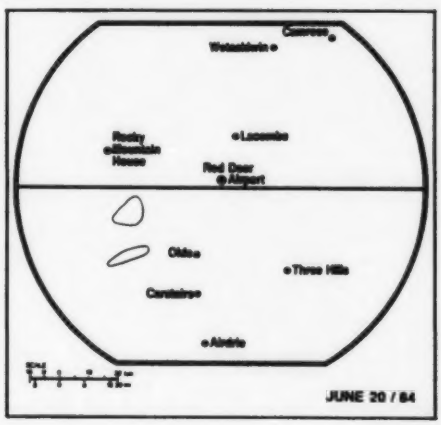




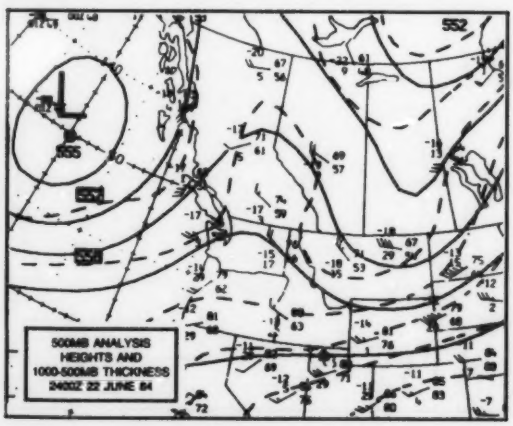
19 JUNE 84

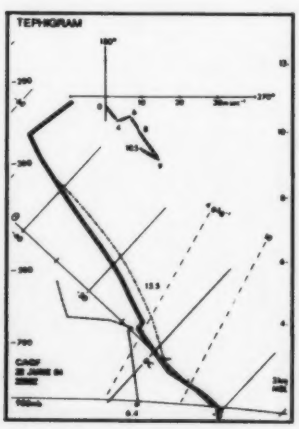


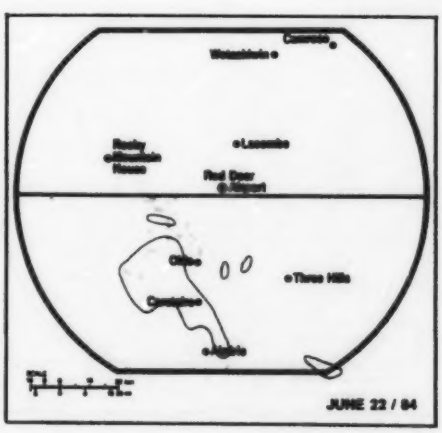




20 JUNE 84

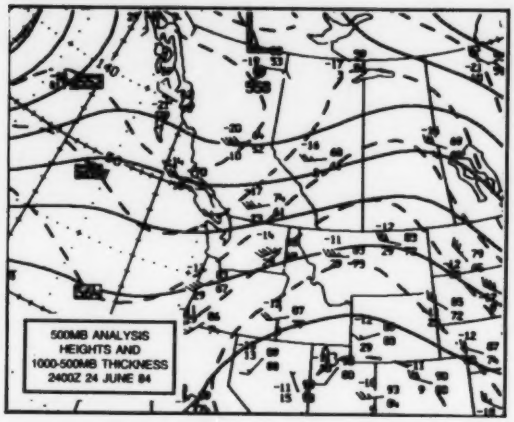


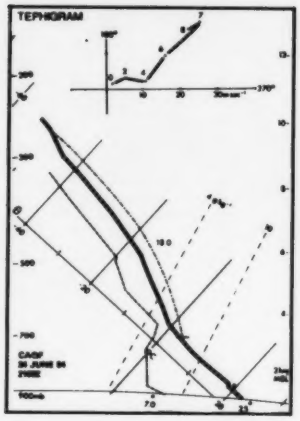


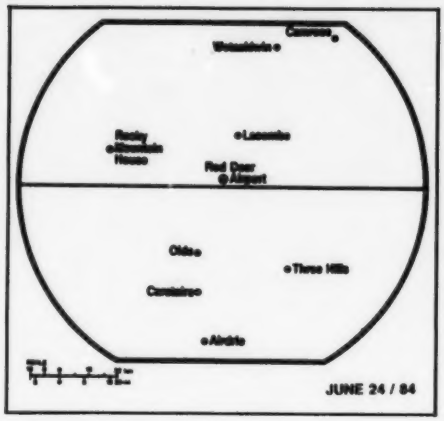


22 JUNE 84

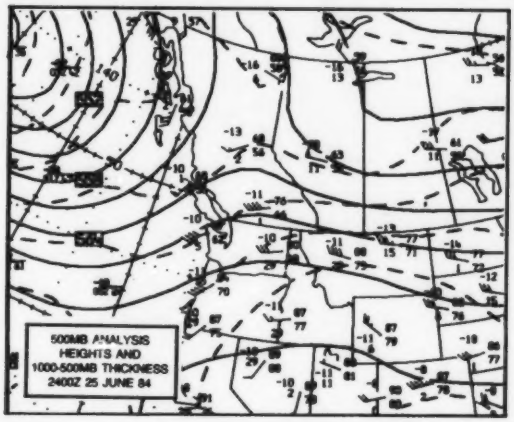
Appendix 6. (continued)

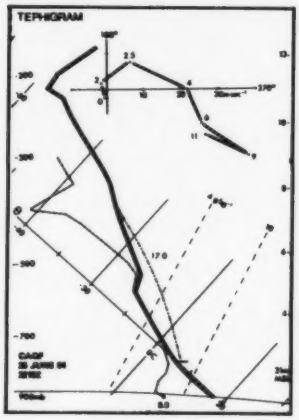


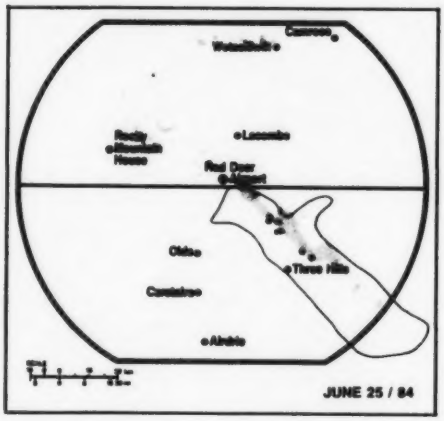




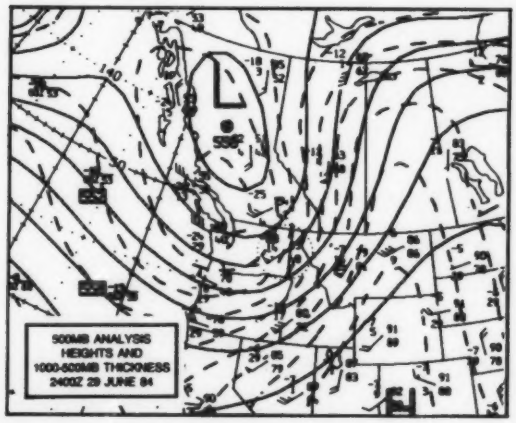
24 JUNE 84

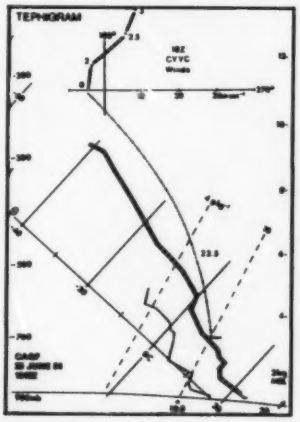


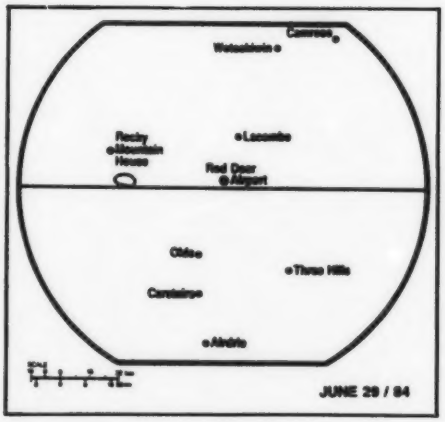




25 JUNE 84

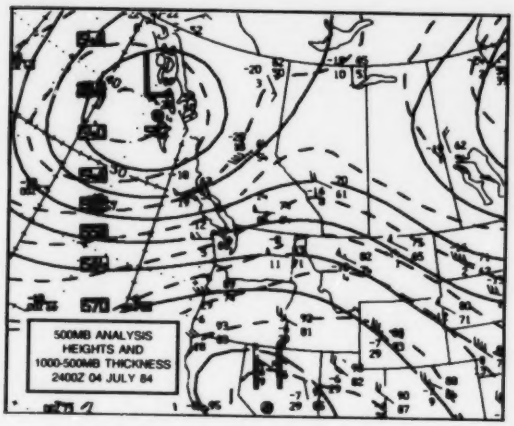


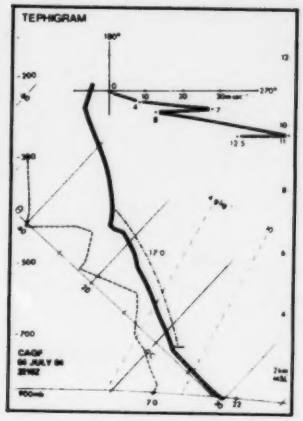


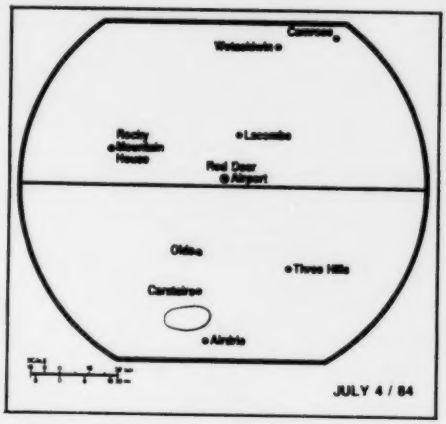


29 JUNE 84

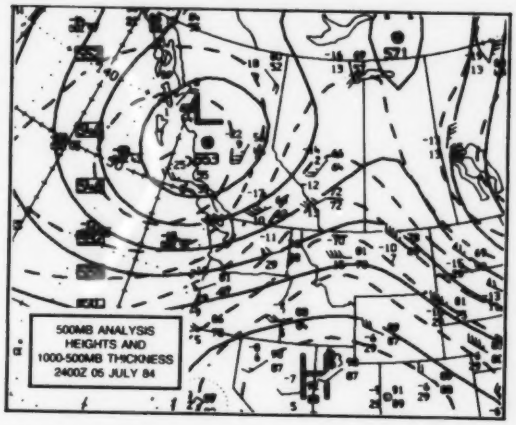
Appendix 6. (continued)

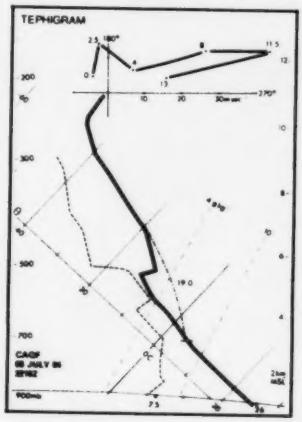


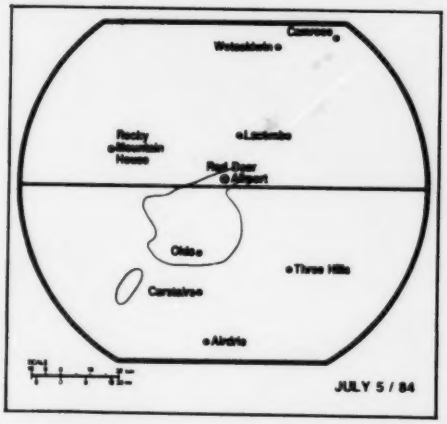




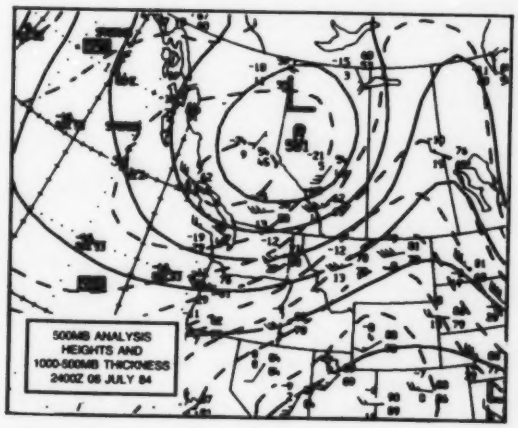
4 JULY 84

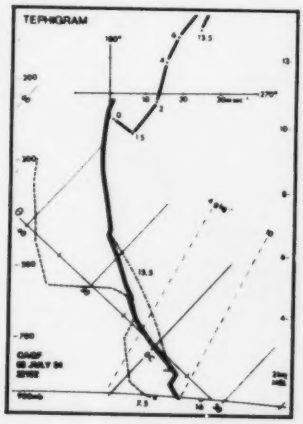


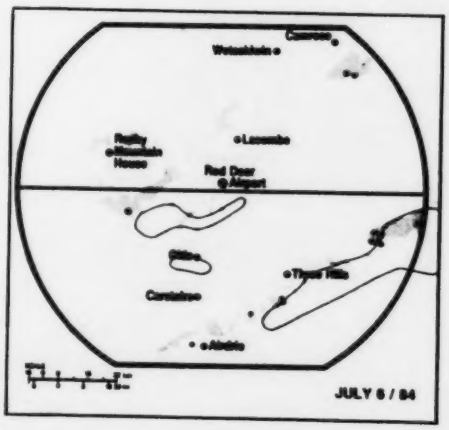




5 JULY 84

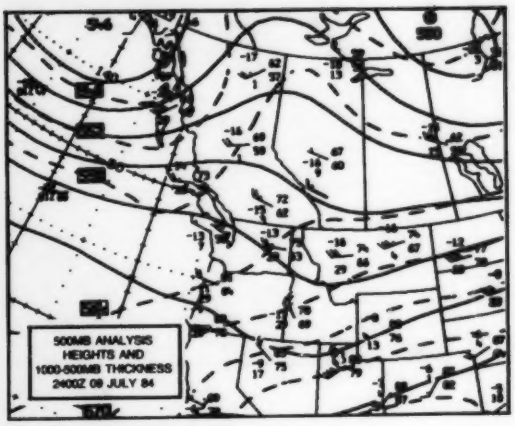


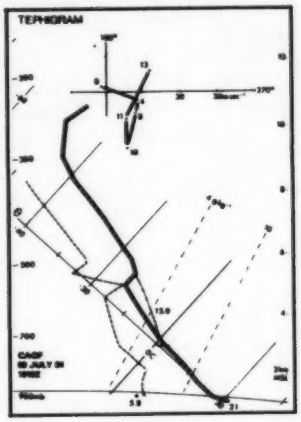


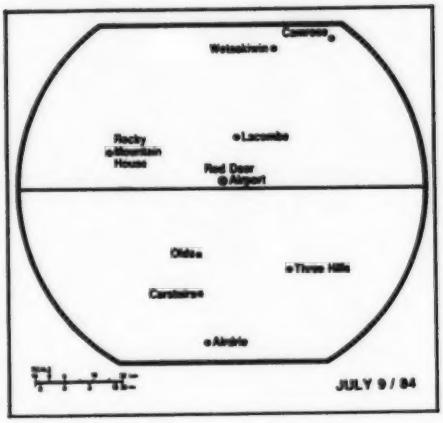


6 JULY 84

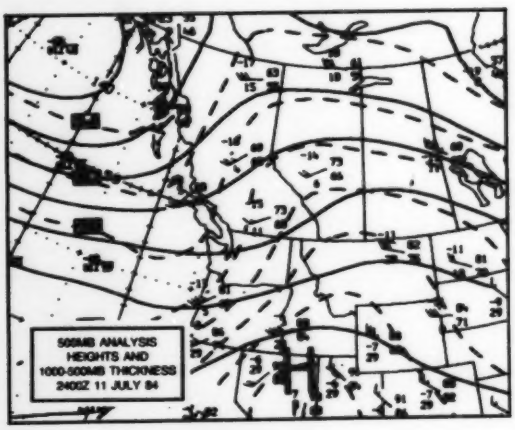
Appendix 6. (continued)

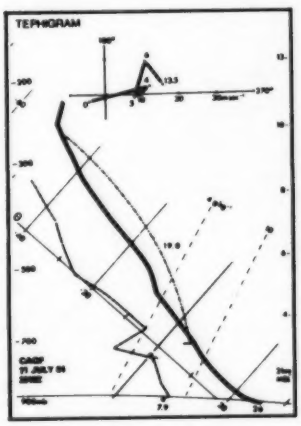


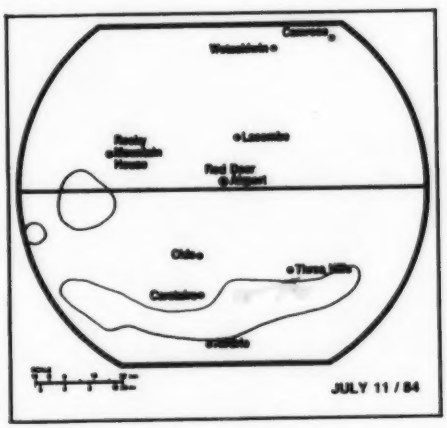




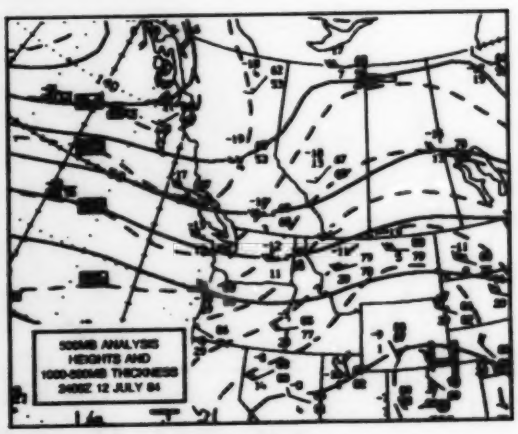
9 JULY 84

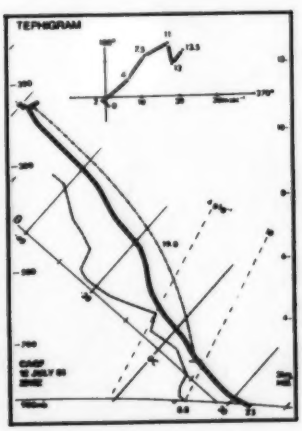


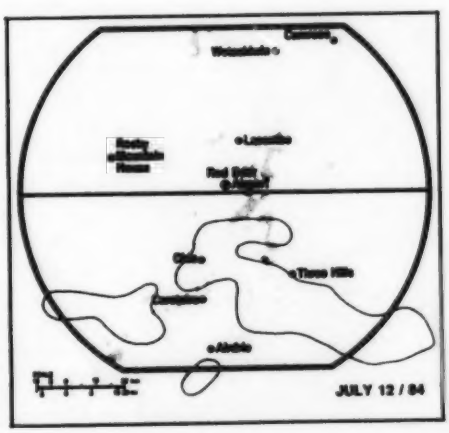




11 JULY 84

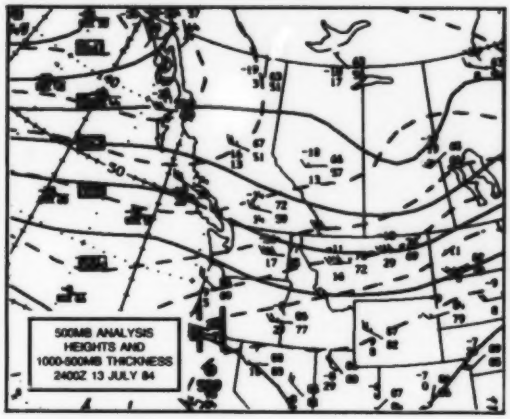


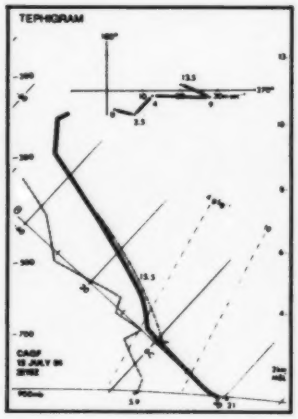


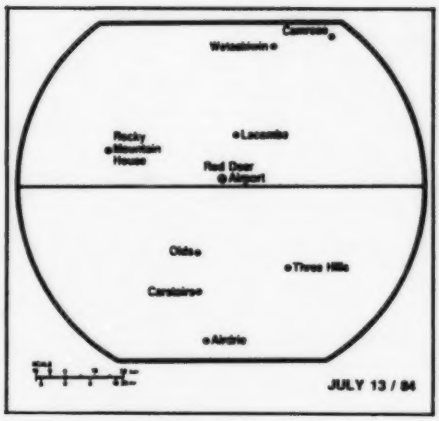


12 JULY 84

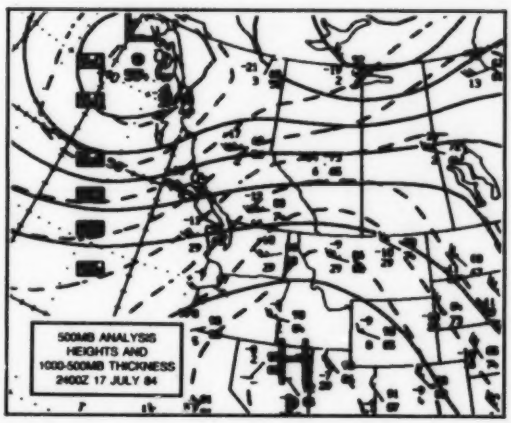
Appendix 6. (continued)

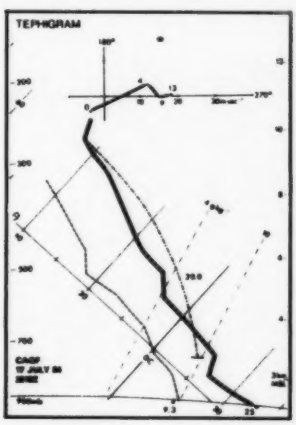


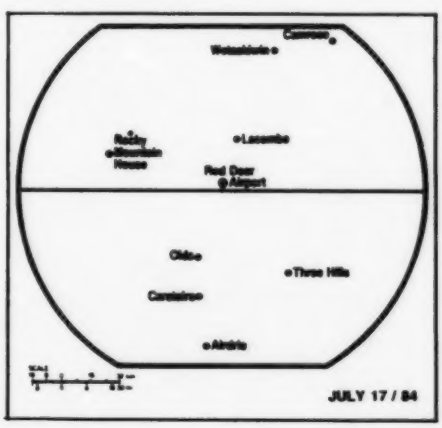




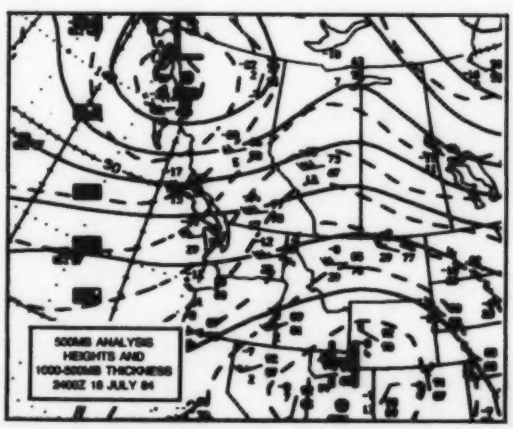
13 JULY 84

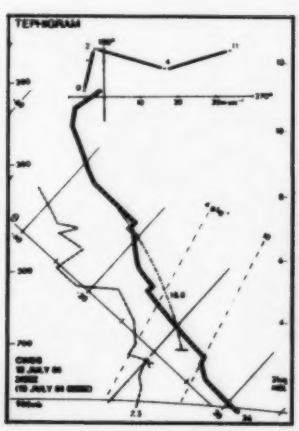


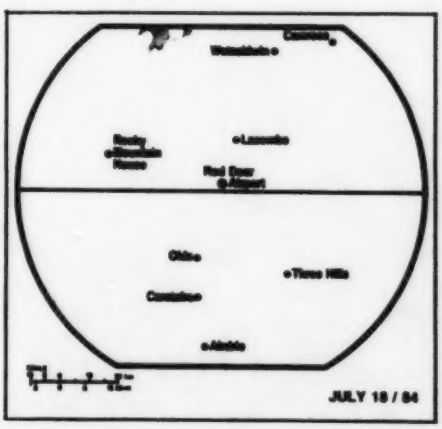




17 JULY 84

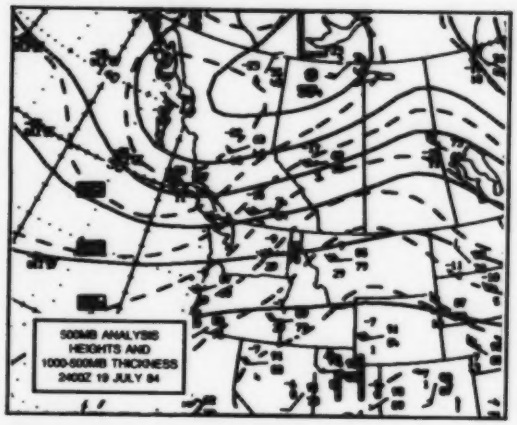


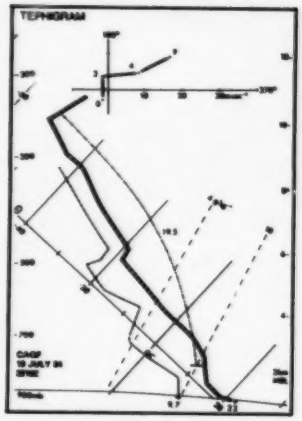


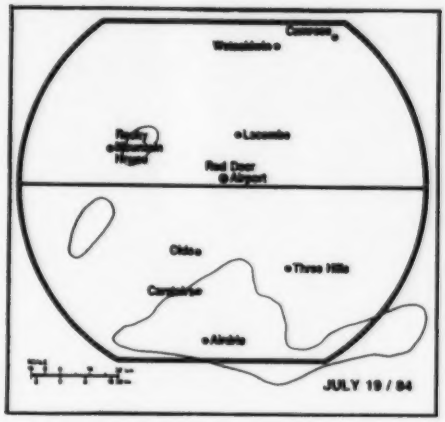


18 JULY 84

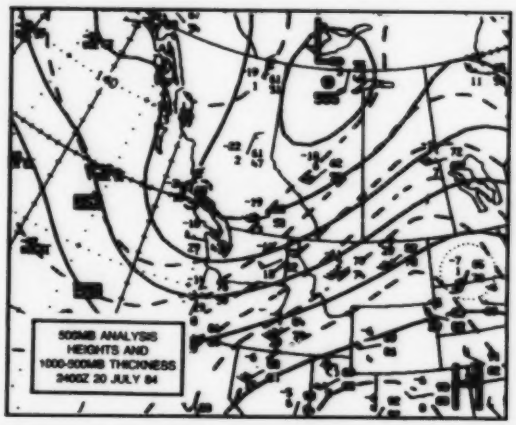
Appendix 6. (continued)

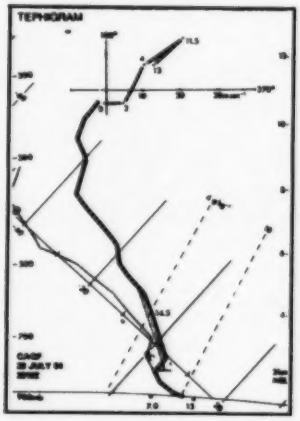


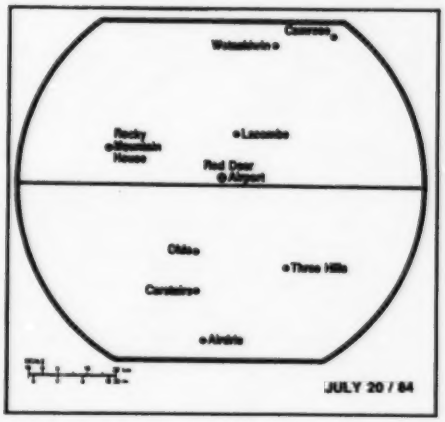




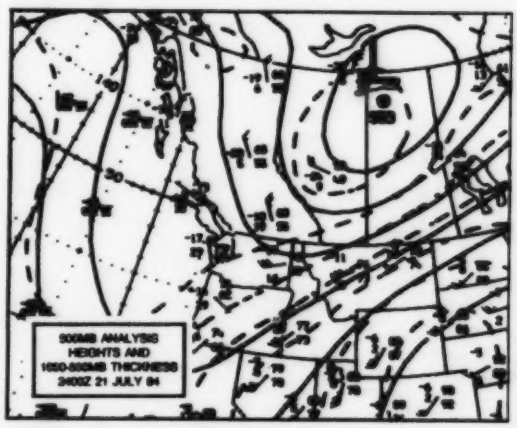
19 JULY 84

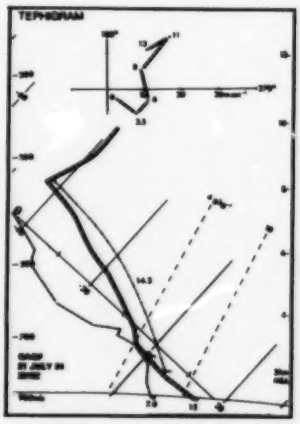


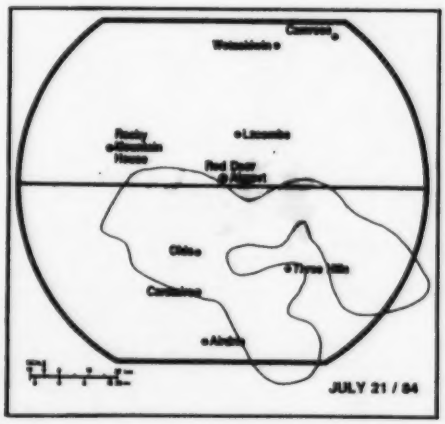




20 JULY 84

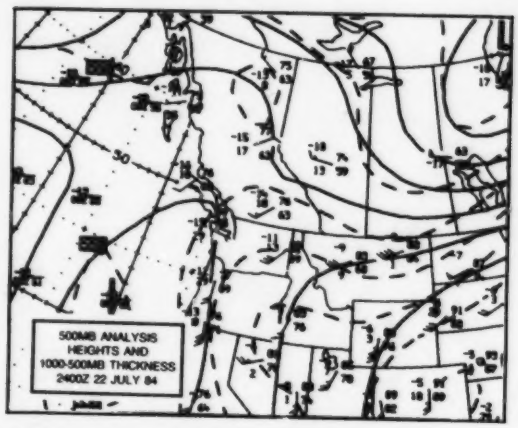


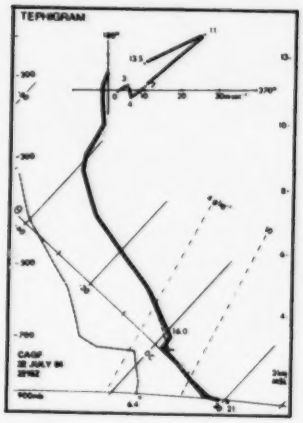


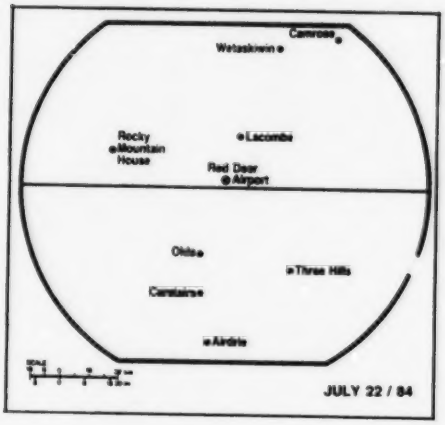


21 JULY 84

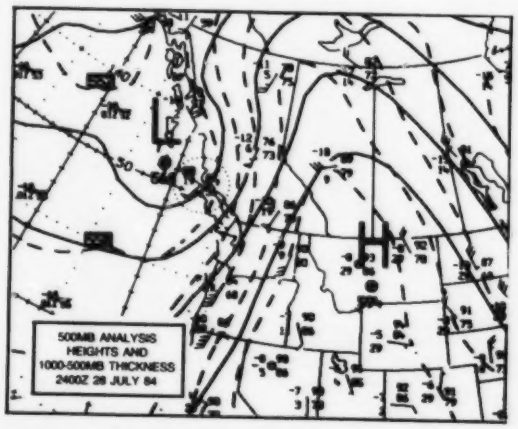
Appendix 6. (continued)

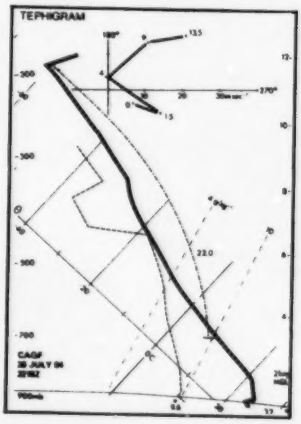


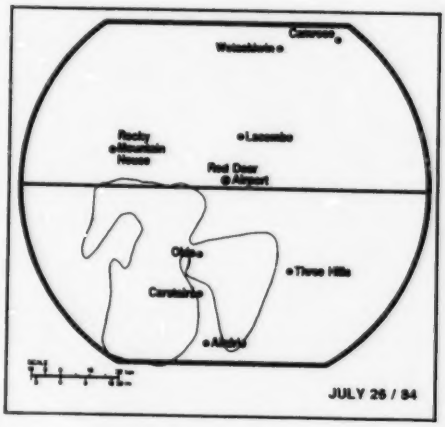




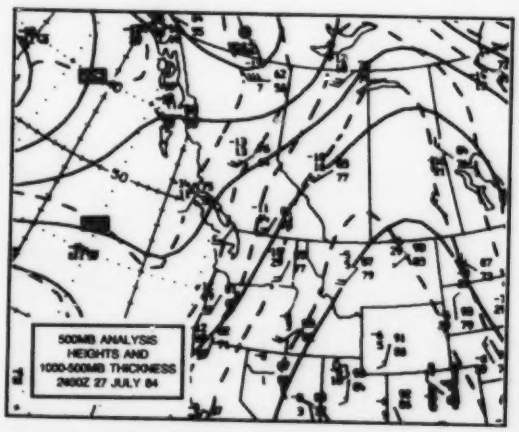
22 JULY 84

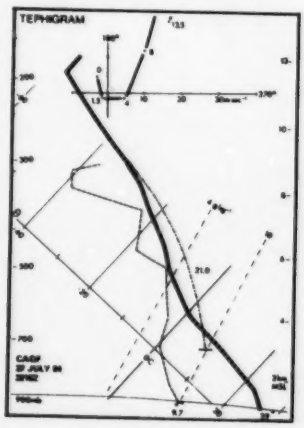


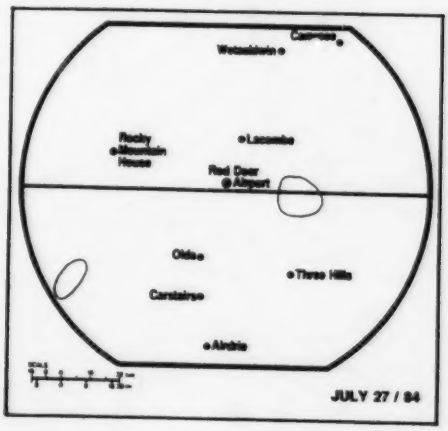




26 JULY 84

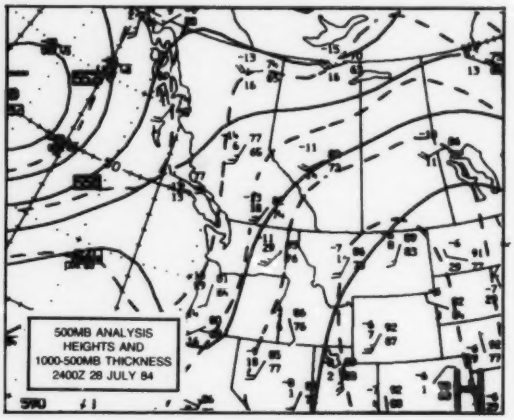


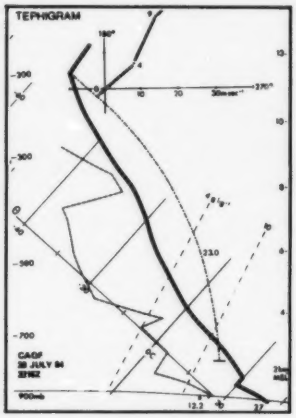


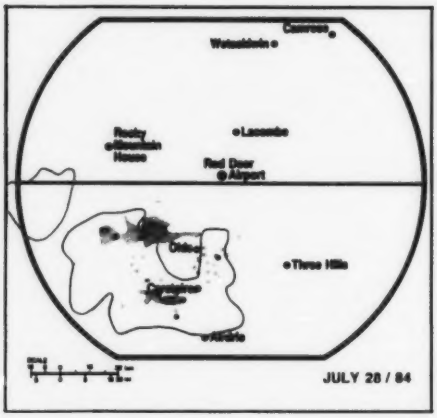


27 JULY 84

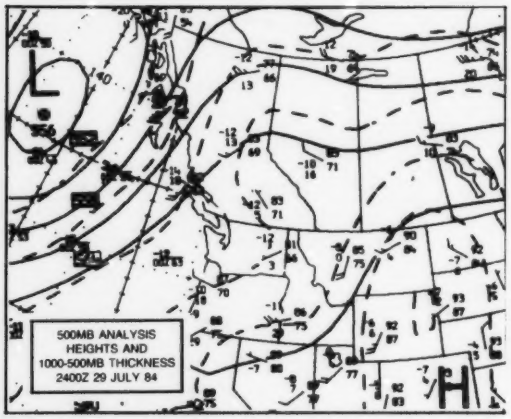
Appendix 6. (continued)

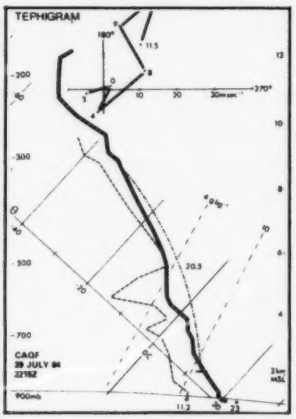


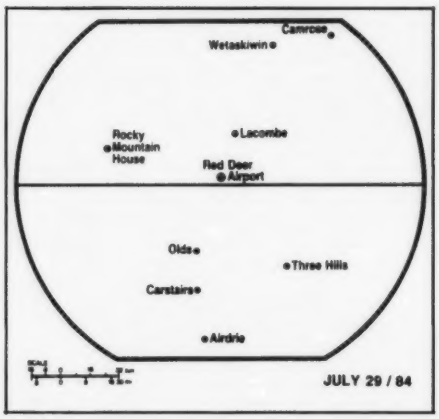




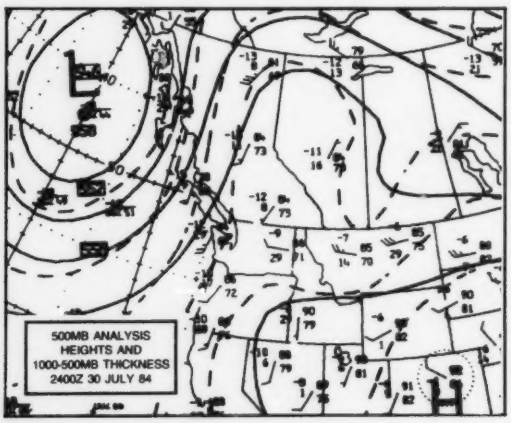
28 JULY 84

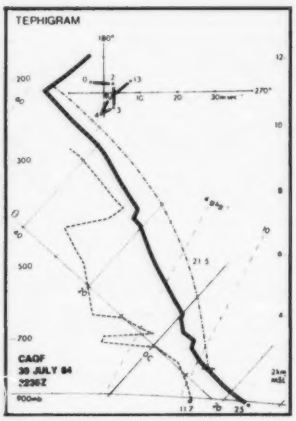


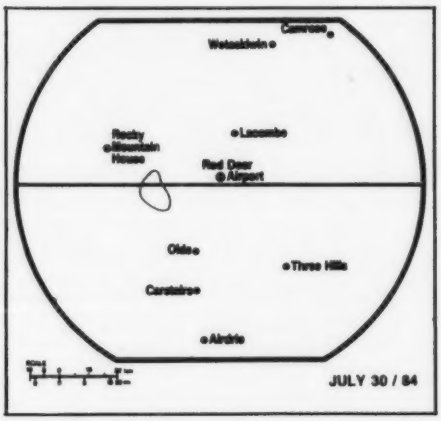




29 JULY 84

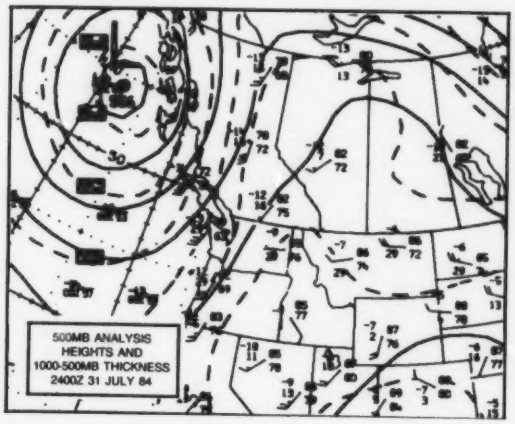


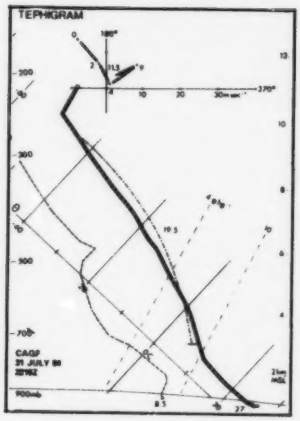


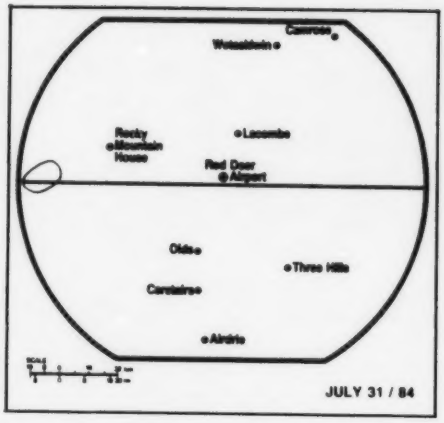


30 JULY 84

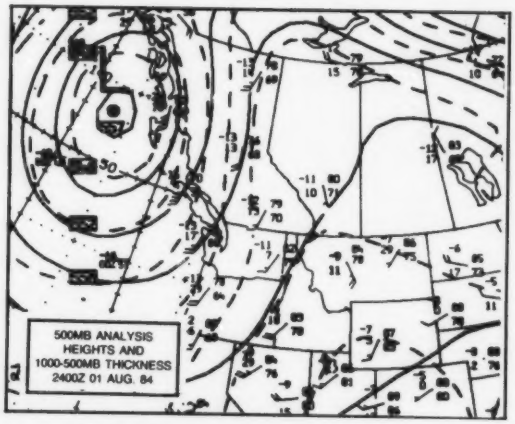
Appendix 6. (continued)

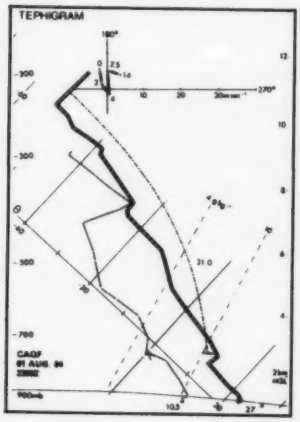


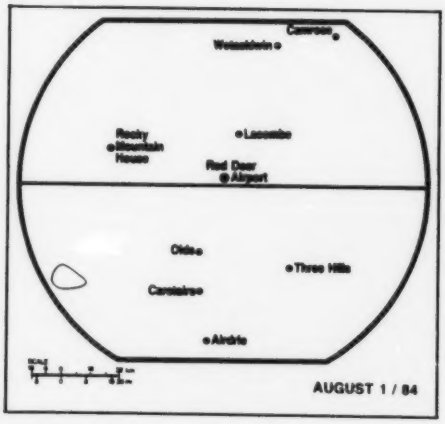




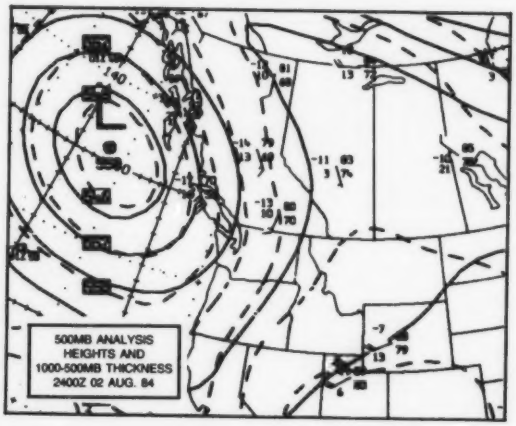
31 JULY 84

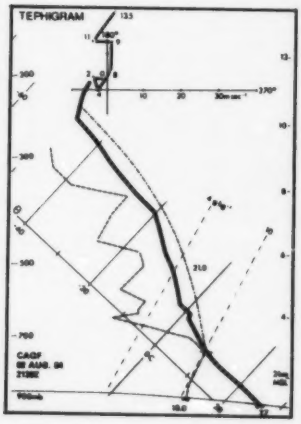


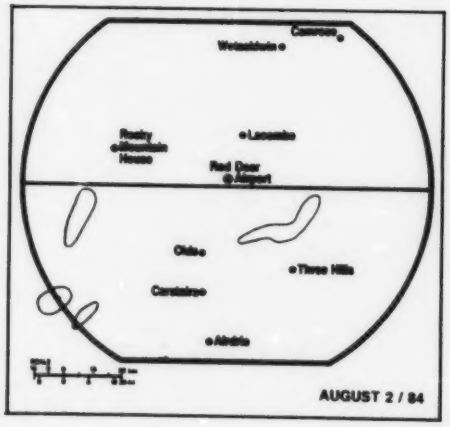




1 AUGUST 84

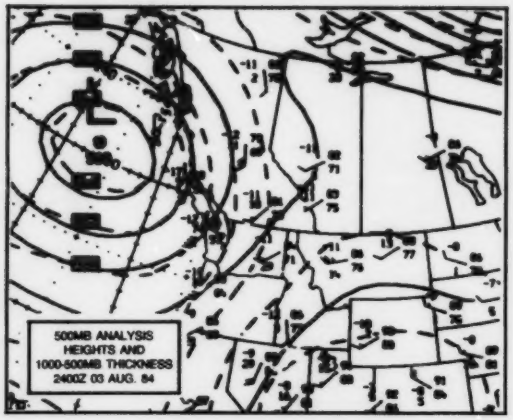


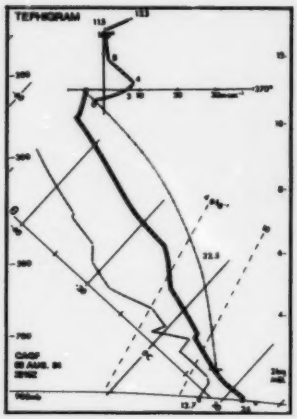


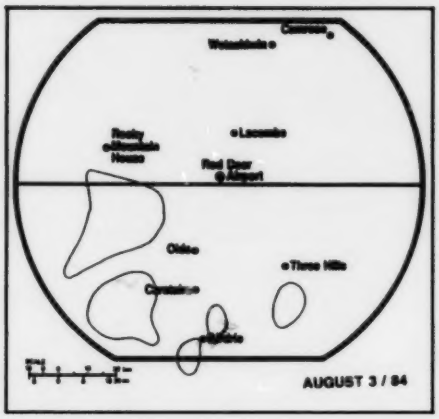


2 AUGUST 84

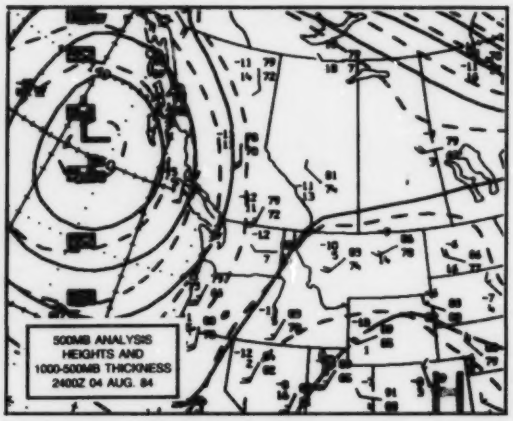
Appendix 6. (continued)

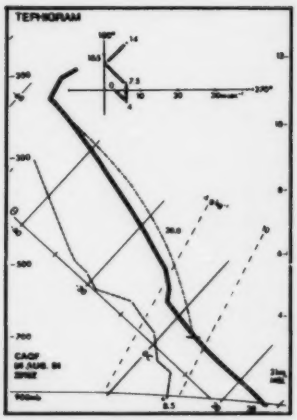


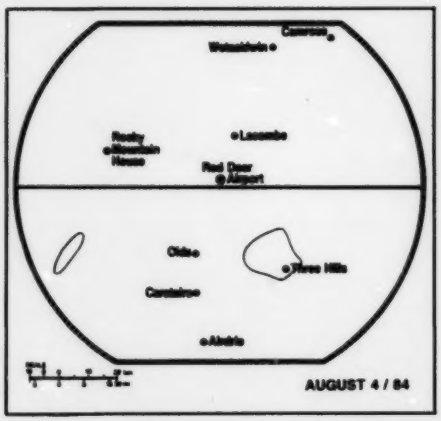




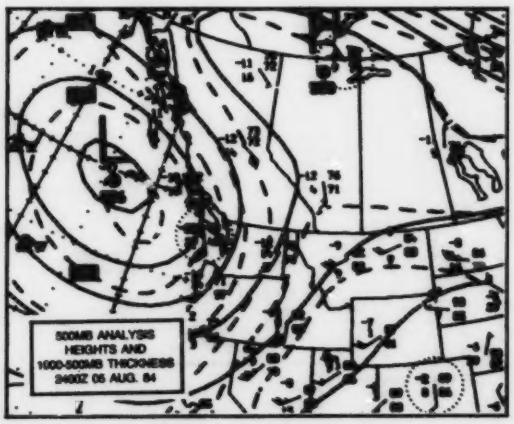
3 AUGUST 84

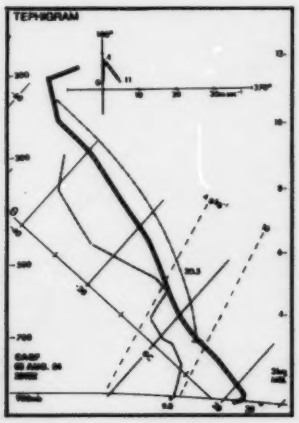


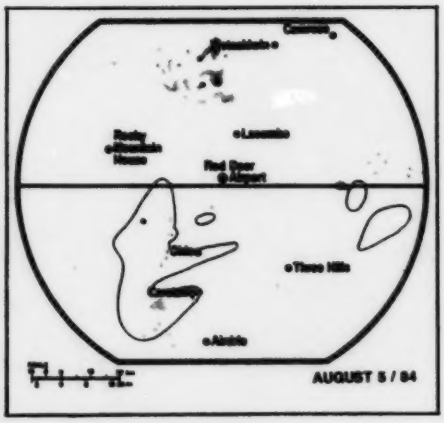




4 AUGUST 84

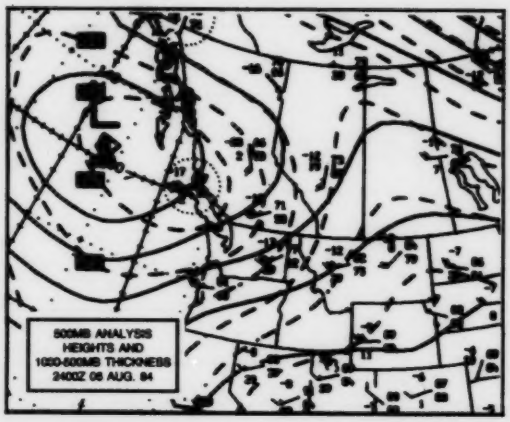


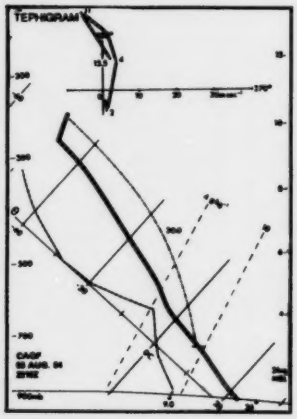


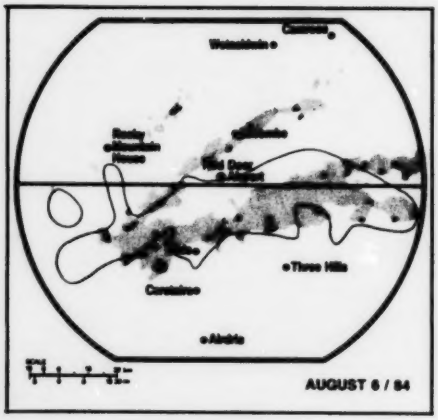


5 AUGUST 84

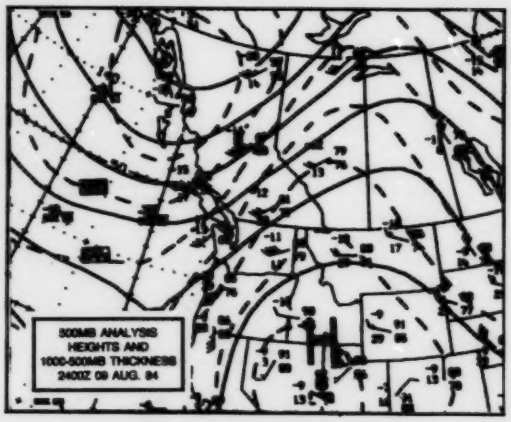
Appendix 6. (continued)

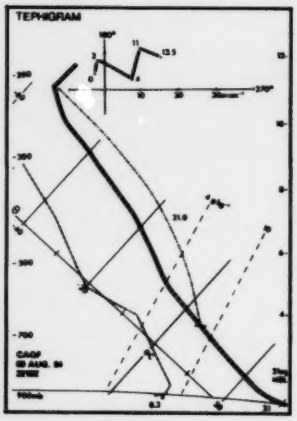


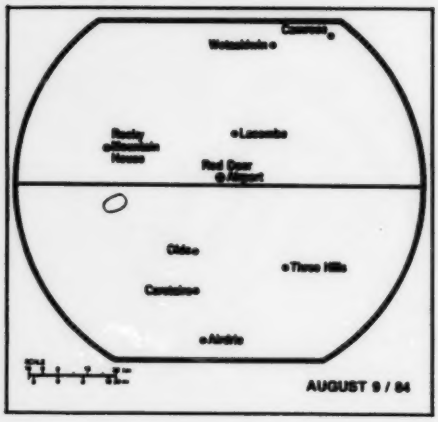




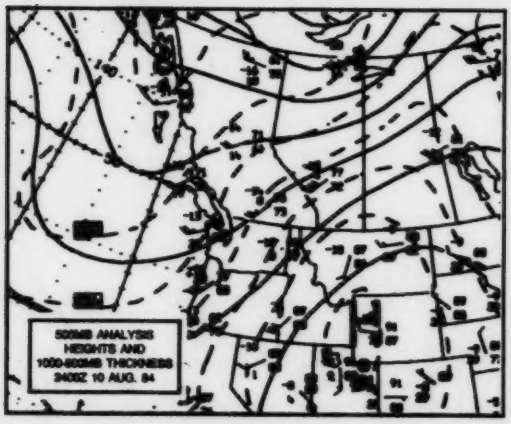
6 AUGUST 84

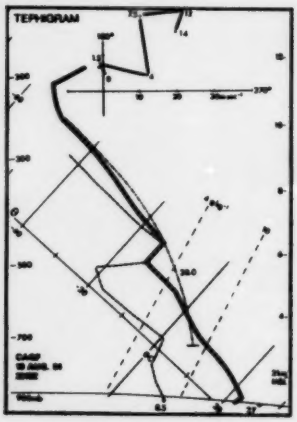


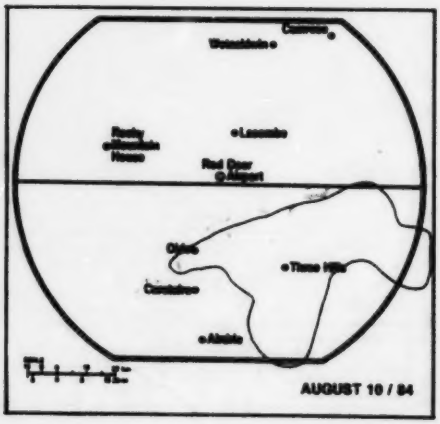




9 AUGUST 84

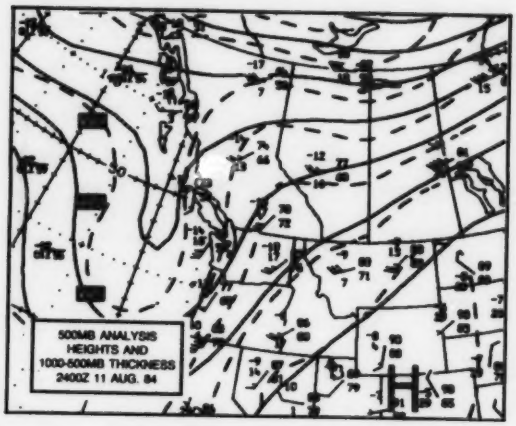


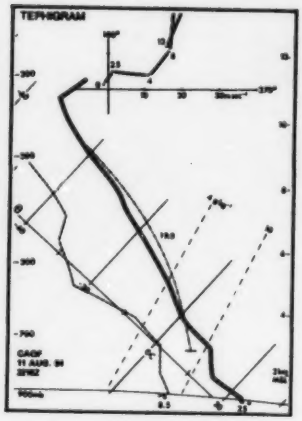


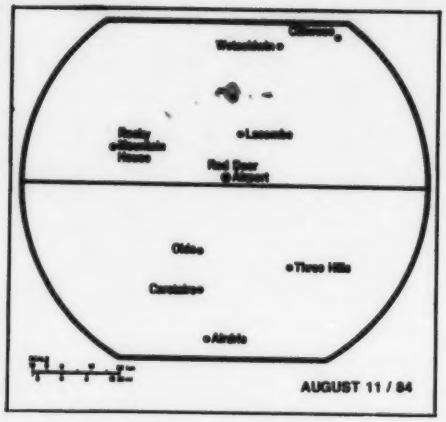


10 AUGUST 84

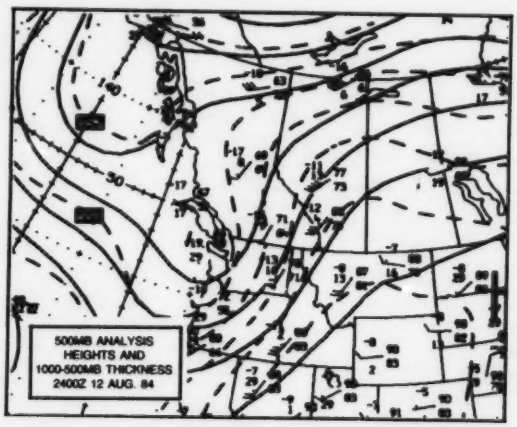
Appendix 6. (continued)

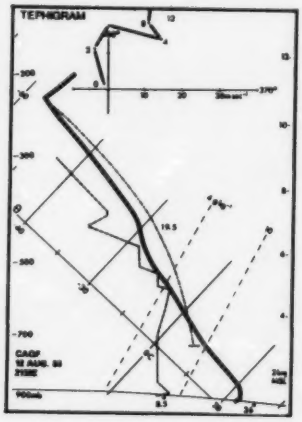


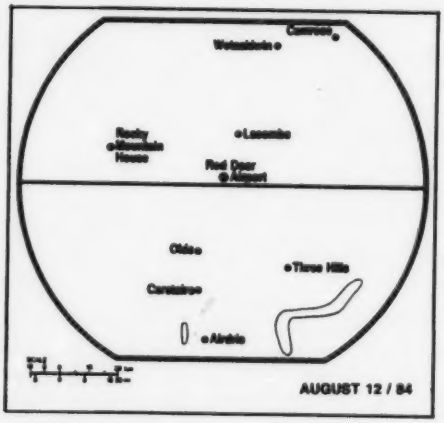




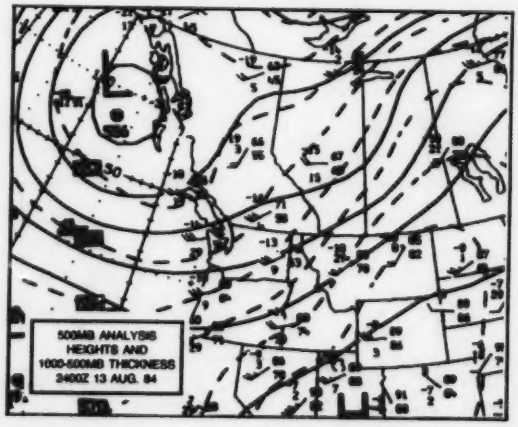
11 AUGUST 84

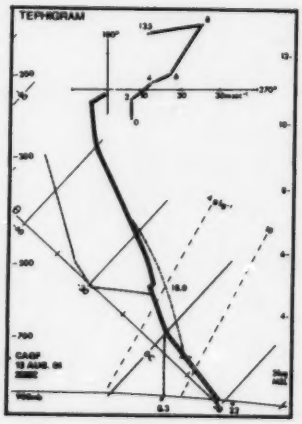


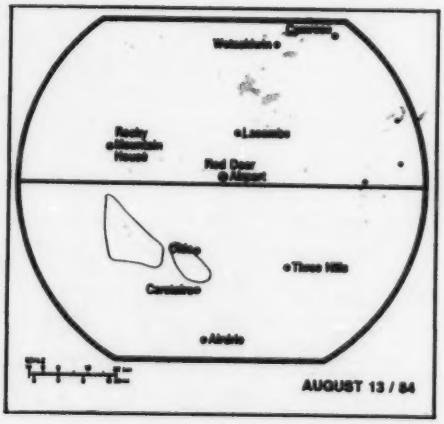




12 AUGUST 84

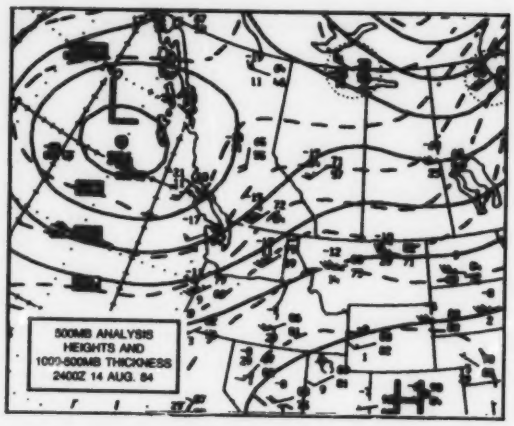


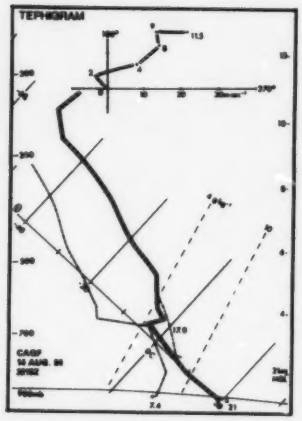


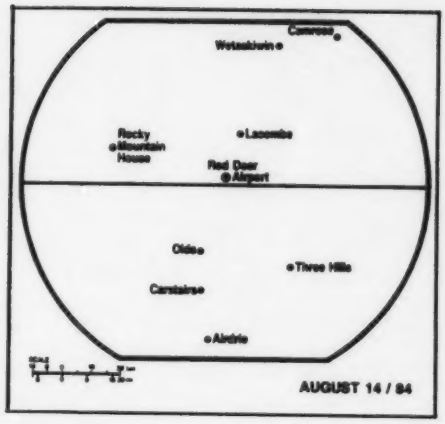


13 AUGUST 84

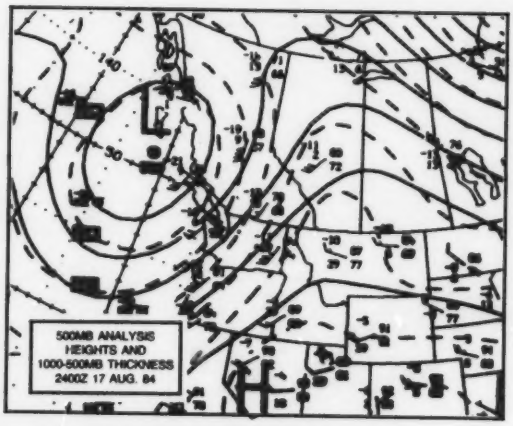
Appendix 6. (continued)

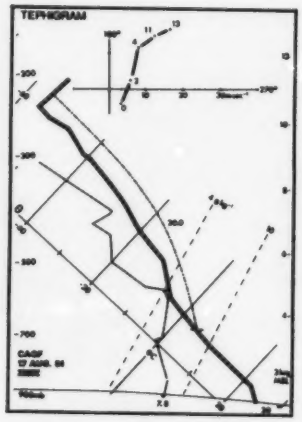


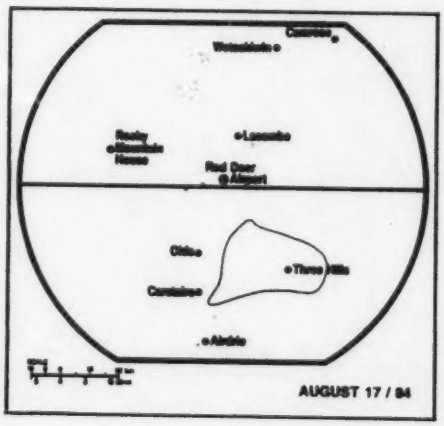




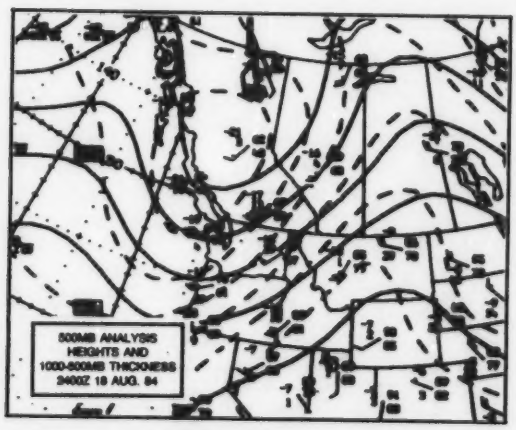
14 AUGUST 84

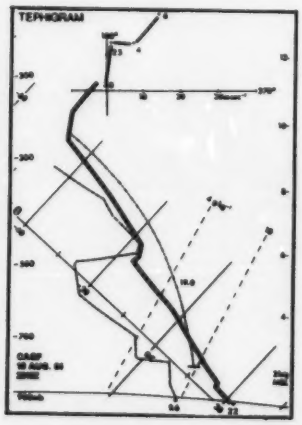


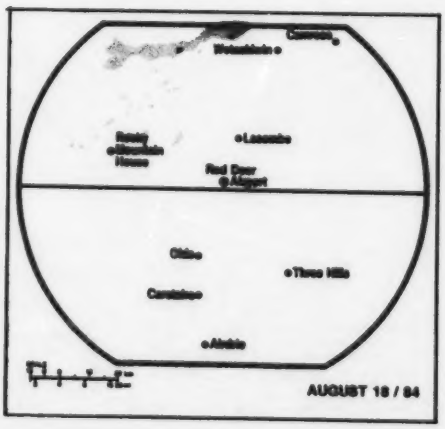




17 AUGUST 84

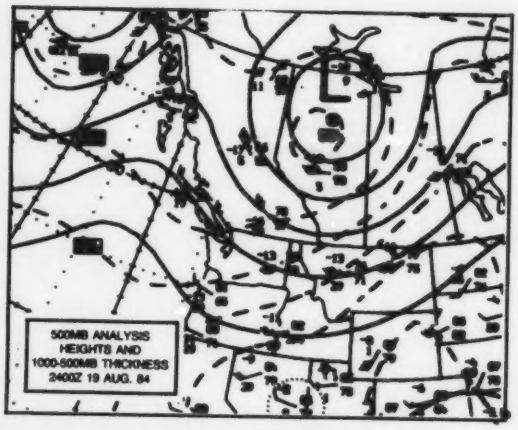


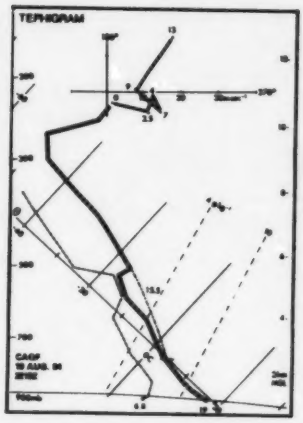


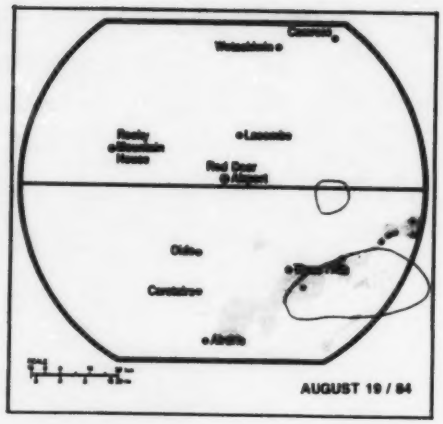


18 AUGUST 84

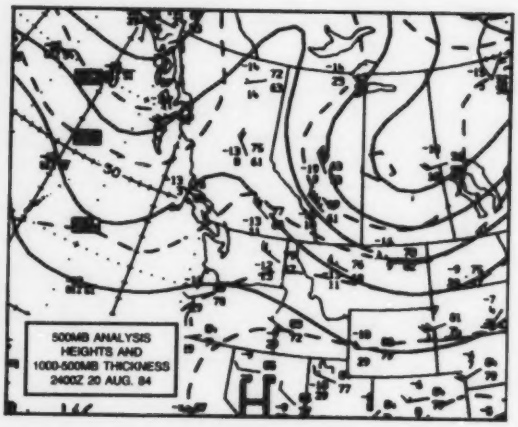
Appendix 6. (continued)

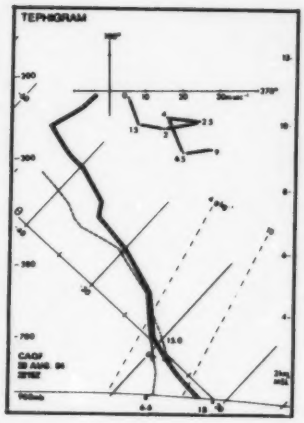


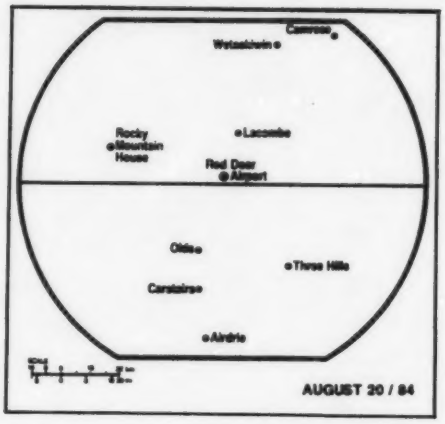




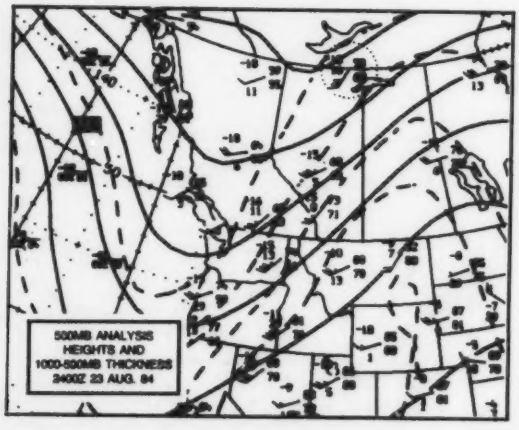
19 AUGUST 84

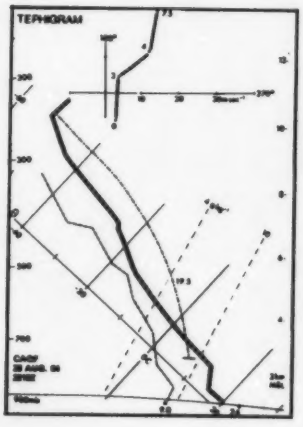


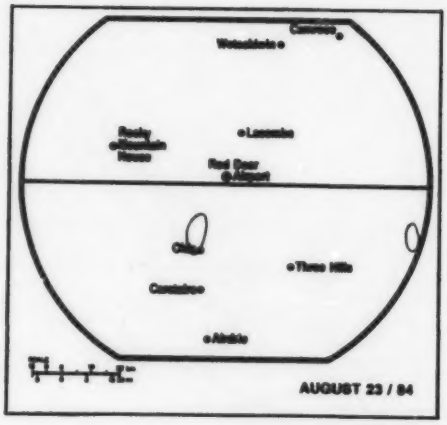




20 AUGUST 84

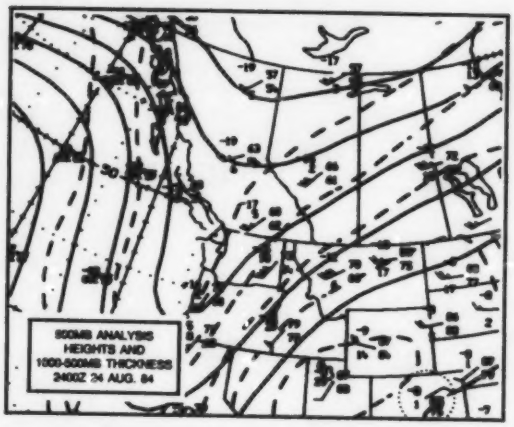


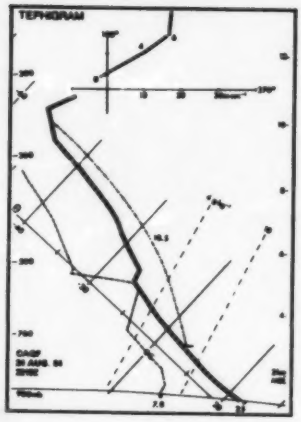


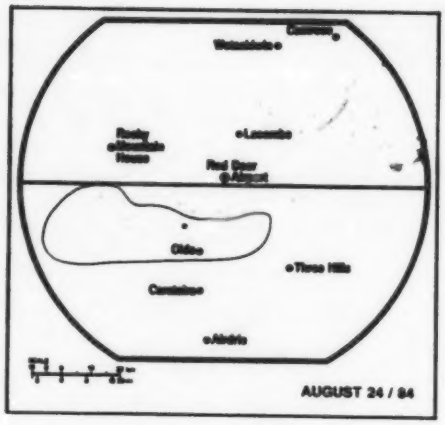


23 AUGUST 84

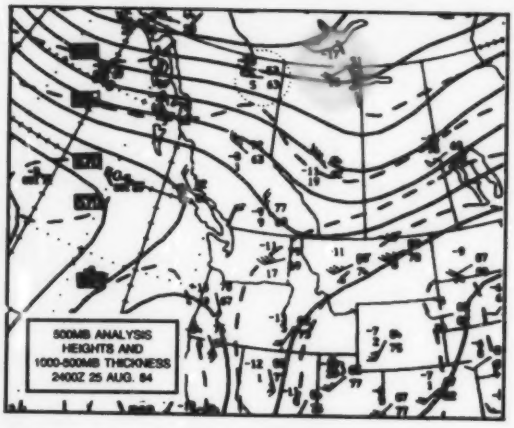
Appendix 6. (continued)

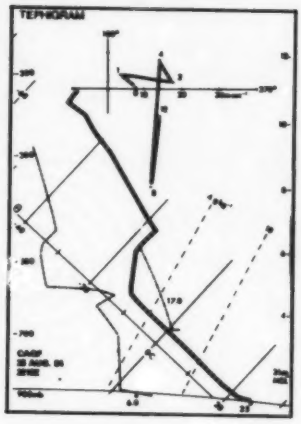


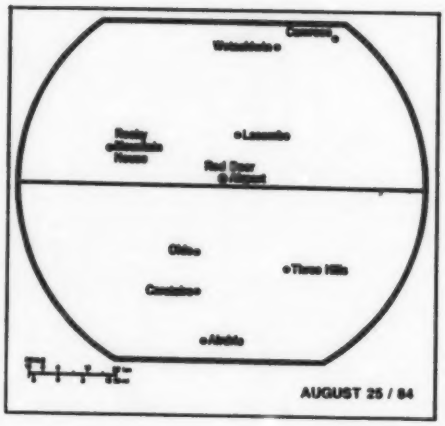




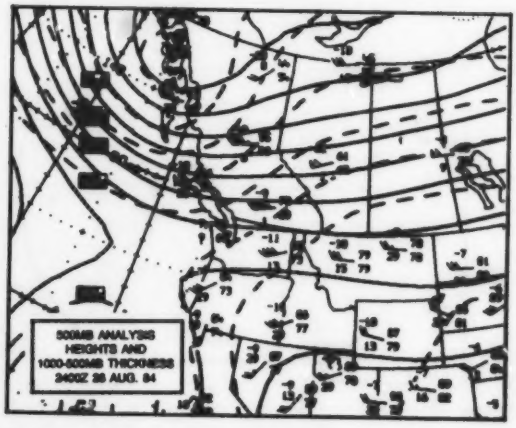
24 AUGUST 84

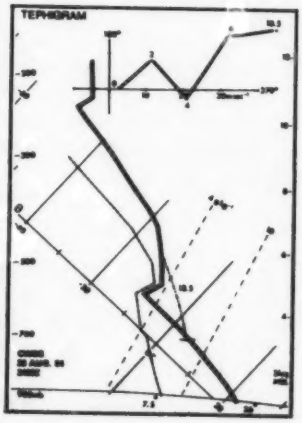


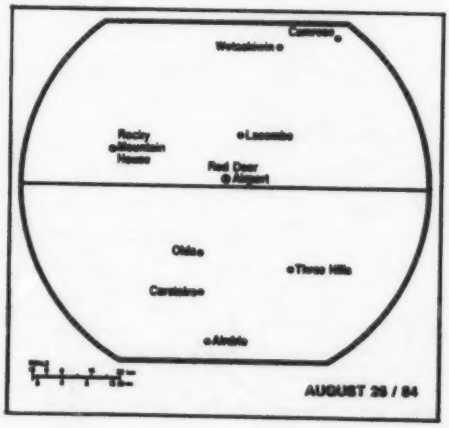




25 AUGUST 84

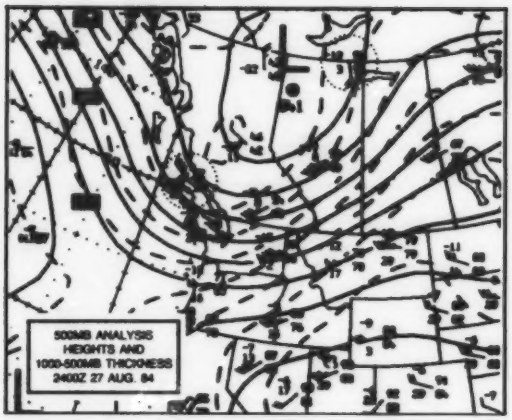


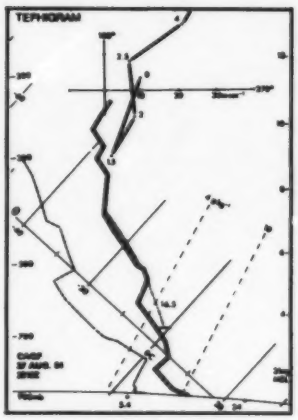


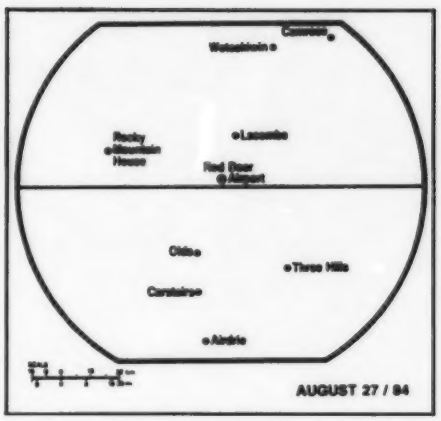


26 AUGUST 84

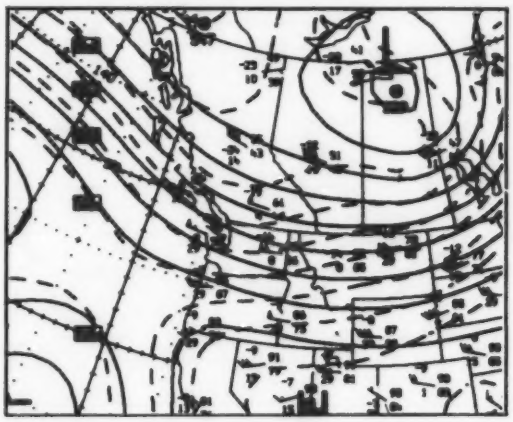
Appendix 6. (continued)

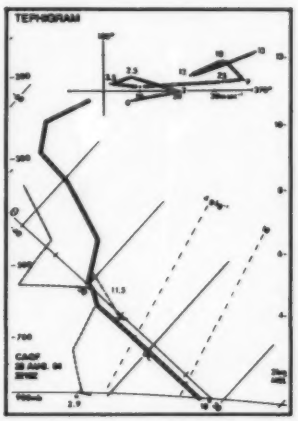


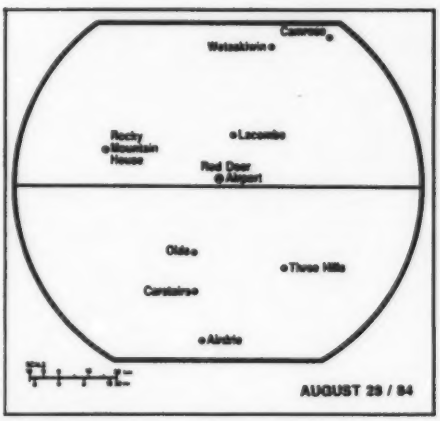




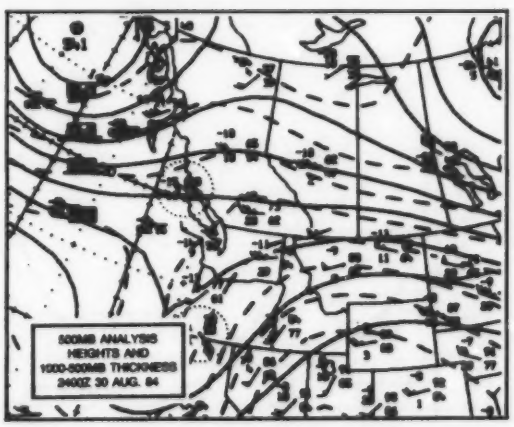
27 AUGUST 84

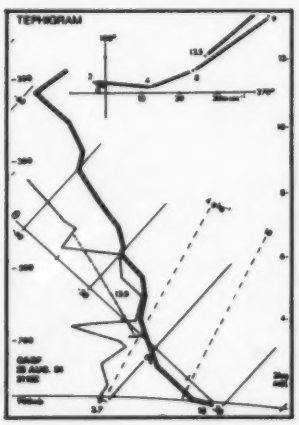


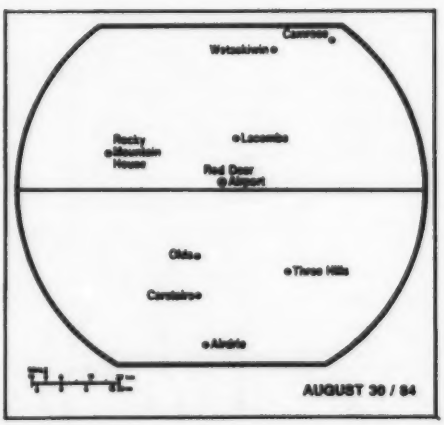




28 AUGUST 84







30 AUGUST 84

Appendix 7. Monthly summary of hail days and hail reports from 1974 - 1984

NORTHERN AREA

Years	June	July	August	September	Total
		Number of Hail Days/Month			
1984	10	9	13	1	33
1983	8	17	10	—	35
1982	7	16	13	2	38
1981	19	14	9	2	44
1980	18	21	17	2	58
1979	17	18	8	7	50
1978	20	18	8	2	48
1977	13	17	14	3	47
1976	11	16	12	2	41
1975	16	13	15	5	49
1974	12	16	13	2	43
Avg. 1974-84	14	16	12	3	44
Avg. 1957-84	12	15	10	2	39
		Number of Hail Reports/Month			
1984	138	368	512	3	1021
1983	119	570	228	—	917
1982	209	630	744	14	1597
1981	423	267	77	2	769
1980	93	939	492	2	1526
1979	315	993	211	157	1676
1978	537	820	227	12	1596
1977	207	426	257	192	1082
1976	307	733	526	8	1574
1975	207	1165	721	57	2150
1974	269	1153	298	7	1727
Avg. 1974-84	257	733	390	41	1421
Avg. 1957-84	319	723	336	23	1400

SOUTHERN AREA

Years	June	July	August	September	Total
		Number of Hail Days/Month			
1984	12	11	12	3	38
1983	12	17	8	—	37
1982	12	15	12	1	40
1981	20	13	13	2	48
1980	16	18	19	3	56
1979	14	22	11	7	54
1978	13	16	7	5	41
1977	11	18	11	3	43
1976	8	13	10	1	32
1975	19	18	14	5	56
1974	10	10	12	1	33
Avg. 1974-84	13	16	12	3	43
Avg. 1957-84	12	15	9	2	38
		Number of Hail Reports/Month			
1984	207	518	587	9	1321
1983	156	660	216	—	1032
1982	71	259	500	4	834
1981	329	469	258	2	1058
1980	317	1013	151	92	1573
1979	84	633	162	290	1169
1978	458	425	55	15	953
1977	162	474	132	199	967
1976	76	295	329	36	736
1975	357	394	319	9	1079
1974	328	422	523	5	1278
Avg. 1974-84	231	506	294	60	1091
Avg. 1957-84	279	606	305	32	1222

Appendix 7. (continued)

OUTSIDE PROJECT AREA

Years	June	July	August	September	Total
		Number of Hail Days/Month			
1984	18	12	17	3	50
1983	18	19	10	1	48
1982	19	21	12	3	55
1981	21	18	14	2	55
1980	27	22	23	4	76
1979	21	20	15	6	62
1978	16	24	16	8	64
1977	22	25	18	4	69
1976	16	19	15	4	54
1975	25	17	18	7	67
1974	16	25	18	3	62
Avg. 1974-84	20	25	16	4	60
		Number of Hail Reports/Month			
1984	128	67	95	7	297
1983	83	210	108	2	402
1982	56	160	52	4	272
1981	177	97	77	2	353
1980	200	153	116	14	483
1979	172	169	100	31	472
1978	379	177	96	53	705
1977	143	207	153	81	584
1976	193	174	203	8	578
1975	244	332	262	28	866
1974	178	559	75	8	820
Avg. 1974-84	178	210	122	22	530

COMBINED NORTHERN AND SOUTHERN AREAS

Years	June	July	August	September	Total
		Number of Hail Days/Month			
1984	14	13	15	3	45
1983	13	19	13	—	45
1982	12	19	16	2	49
1981	23	16	15	3	57
1980	20	23	23	3	69
1979	18	24	14	7	63
1978	20	23	10	5	58
1977	18	22	16	3	59
1976	12	18	15	3	48
1975	23	20	18	6	67
1974	12	17	15	2	46
Avg. 1974-84	17	19	15	3	55
Avg. 1957-84	15	18	12	2	47
		Number of of Hail Reports/Month			
1984	345	886	1099	12	2342
1983	275	1230	444	—	1949
1982	280	889	1244	18	2431
1981	752	736	335	4	1827
1980	410	1952	643	94	3099
1979	399	1626	373	447	2845
1978	995	1245	282	27	2549
1977	369	900	389	391	2079
1976	383	1028	855	44	2310
1975	564	1559	1040	66	3229
1974	597	1575	821	12	3005
1974-84	488	1239	684	101	2512
1957-84	597	1329	641	55	2622

Appendix 7. (continued)
Daily log of maximum hail size reported from NORTHERN AREA (Twp. 37-47)

Date 1984		Shot	Pea	Grape	Walnut	Golfball	>Golfball	Unknown	No Hail	Tot. Hail
June	5	—	2	—	—	—	—	—	—	2
	12	—	9	9	—	—	—	—	—	18
	15	1	2	—	—	—	—	—	—	3
	16	1	—	—	—	—	—	—	—	1
	17	—	4	—	—	—	—	—	—	4
	18	1	10	9	3	1	—	—	—	24
	19	1	1	—	—	—	—	—	—	2
	22	—	—	—	—	—	—	—	12	—
	24	—	3	1	—	—	—	—	22	4
	25	11	37	9	1	—	—	6	204	64
	29	1	14	1	—	—	—	—	184	16
July	5	11	32	10	—	—	—	—	207	53
	6	28	60	16	1	1	—	—	249	106
	8	—	—	—	—	—	—	—	9	—
	11	—	—	—	—	—	—	—	48	—
	12	13	29	13	—	—	—	—	205	55
	17	4	18	5	1	—	—	2	142	30
	18	6	7	3	—	—	—	—	93	16
	19	—	—	—	—	—	—	—	12	—
	20	5	6	1	—	—	—	—	92	12
	21	35	43	2	—	—	—	—	186	80
	26	2	4	—	—	—	—	—	81	6
	28	—	—	—	—	—	—	—	19	—
	30	—	7	3	—	—	—	—	192	10
Aug.	2	1	—	—	—	—	—	—	53	1
	3	1	4	—	—	—	—	—	65	5
	4	—	1	—	—	—	—	—	11	1
	5	5	30	33	3	—	—	—	210	71
	6	14	67	58	27	3	—	1	285	170
	10	1	2	—	—	—	—	—	36	3
	11	1	12	10	3	—	—	—	96	26
	12	—	—	—	—	—	—	—	15	—
	13	13	32	12	2	2	—	—	374	61
	17	3	14	9	—	—	—	—	162	26
	18	12	50	34	2	3	—	—	165	101
	19	2	2	—	—	—	—	—	15	4
	20	—	—	—	—	—	—	—	12	—
	22	—	—	—	—	—	—	—	3	—
	24	5	29	4	—	—	—	—	268	38
	25	1	3	1	—	—	—	—	45	5
Sept.	6	2	1	—	—	—	—	—	—	3

Appendix 7. (continued)

Daily log of maximum hail size reported from SOUTHERN AREA (Twp. 26-36)

Date 1984		Shot	Pea	Grape	Walnut	Golfball	>Golfball	Unknown	No Hail	Tot. Hail
June	6	—	2	—	—	—	—	—	—	2
	12	—	1	—	—	—	—	—	—	1
	15	—	6	—	—	—	—	—	—	6
	16	2	11	6	3	1	—	—	—	23
	17	1	5	9	3	—	—	1	—	19
	18	1	7	16	8	1	—	—	—	33
	19	1	9	2	—	—	—	—	—	12
	20	1	—	—	—	—	—	—	—	1
	21	1	—	—	—	—	—	—	—	1
	22	12	24	4	—	—	—	—	93	40
	25	7	26	20	9	—	—	6	97	68
	29	—	1	—	—	—	—	—	12	1
July	4	5	4	—	—	—	—	—	63	9
	5	5	3	1	—	—	—	—	70	9
	6	22	53	37	13	2	—	—	210	127
	8	—	—	—	—	—	—	—	12	—
	11	7	18	4	—	—	—	—	145	29
	12	25	37	18	1	—	—	—	222	81
	17	—	—	—	—	—	—	—	3	—
	18	—	—	—	—	—	—	—	3	—
	19	6	4	—	—	—	—	—	192	10
	20	2	4	—	—	—	—	1	63	7
	21	54	57	3	—	—	—	—	242	114
	26	12	13	1	—	—	—	—	231	26
	28	12	33	31	21	5	2	1	221	105
	30	—	—	1	—	—	—	—	3	1
Aug.	2	3	2	1	—	—	—	—	64	6
	3	3	16	9	—	—	—	1	144	29
	4	—	3	—	—	—	—	—	45	3
	5	4	14	6	1	—	—	—	194	25
	6	20	83	115	47	6	—	1	158	272
	10	2	16	1	—	—	—	—	163	19
	12	4	6	3	—	—	—	—	66	13
	13	—	7	2	—	—	—	—	58	9
	17	—	1	1	—	—	—	—	68	2
	19	31	87	58	7	—	—	—	211	183
	23	1	6	—	—	—	—	—	54	7
	24	5	11	2	1	—	—	—	144	19
	25	—	—	—	—	—	—	—	30	—
Sept.	1	—	2	2	2	—	—	—	—	6
	6	—	1	1	—	—	—	—	—	2
	13	—	1	—	—	—	—	—	—	1

Appendix 7. (continued)

Daily log of maximum hail size reported from OUTSIDE the project area

Date 1984		Shot	Pea	Grape	Walnut	Golfball	> Golfball	Unknown	No Hail	Tot. Hail
June	4	1	—	—	—	—	—	—	—	1
	5	—	1	—	1	—	—	—	—	2
	6	—	2	—	—	—	—	—	—	2
	7	—	2	—	—	—	—	—	—	2
	11	—	—	1	—	—	—	—	—	1
	12	—	8	7	4	—	—	—	—	19
	13	—	—	1	—	—	—	—	—	1
	15	—	5	5	1	—	—	—	—	11
	16	—	10	7	—	—	—	1	—	18
	17	—	2	6	—	—	—	—	—	8
	18	—	3	—	—	—	—	—	—	3
	19	1	9	1	—	—	—	—	—	11
	20	—	4	—	—	—	—	—	—	4
	21	—	1	—	—	—	—	—	—	1
	22	1	9	—	1	—	—	—	—	11
	24	—	2	4	—	—	—	1	—	7
	25	—	1	2	—	—	—	—	—	3
	29	—	6	6	3	3	4	1	—	23
July	5	—	3	5	1	—	—	—	—	9
	6	2	6	3	1	—	—	—	1	12
	7	—	1	—	—	—	—	—	—	1
	8	—	2	—	—	—	—	—	—	2
	12	1	6	2	6	—	—	—	—	15
	20	—	3	—	—	—	—	—	—	3
	21	1	11	1	—	—	—	—	—	13
	26	—	4	1	—	—	—	—	—	5
	27	—	2	—	—	—	—	—	—	2
	28	—	2	1	—	—	—	—	—	3
	30	—	—	1	—	—	—	—	—	1
	31	—	1	—	—	—	—	—	—	1
Aug.	1	—	—	1	—	—	—	—	—	1
	2	—	1	1	—	—	—	—	—	2
	3	—	2	1	—	—	—	—	—	3
	4	—	2	—	—	—	—	—	—	2
	5	—	2	—	—	—	—	—	—	2
	6	—	9	10	3	1	1	—	3	24
	9	—	—	—	—	—	—	1	—	1
	10	—	1	1	—	—	—	—	—	2
	11	—	1	2	—	—	—	—	—	3
	12	—	5	—	—	—	—	—	—	5
	13	1	3	—	2	1	—	—	3	7
	18	—	3	12	4	1	—	—	1	20
	19	—	5	3	—	—	—	—	6	8
	22	—	—	2	—	—	—	—	—	2
	23	—	2	—	—	—	—	—	—	2
	24	—	—	5	1	1	—	—	7	7
	25	—	—	4	—	—	—	—	—	4
Sept.	1	—	1	1	1	1	—	—	—	4
	9	—	1	—	—	—	—	—	—	1
	13	—	2	—	—	—	—	—	—	2

Appendix 7. (continued) Hail card format

L P C 1

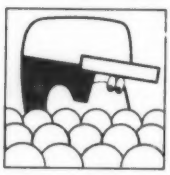
Storm Date: _____ 1984
Day of Week: _____
Location ___¼ S___T___R___W of___

Hail: Began _____ am _____ pm
Lasted for _____ minutes

Rain: Began _____ am _____ pm
Lasted for _____ minutes
Measured _____ mm
Estimated _____ mm

Largest Hailsize:

Shot ☐ Pea ☐ Grape ☐
Walnut ☐ Golfball ☐ Larger ☐



Most Common Hailsize:

Shot ☐ Pea ☐ Grape ☐
Walnut ☐ Golfball ☐ Larger ☐

Average Spacing of Stones
_____ mm
or Depth of Hail _____ mm
or Ground Just Covered ☐

Wind: Light ☐ Moderate ☐
Strong ☐ Severe ☐
Crop: (type) _____
Estimated Damage _____

Remarks _____

_____

_____

_____

Name _____

Address _____

_____

Postal Code _____ **Phone** _____

Thanks for your help. If you would rather phone in your hail report just call collect 886-4431.